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Vol. III

TRANSCRIPT OF RECORD

Supreme Court of the United States

OCTOBER TERM, 1940

No. 666

DETROLA RADIO AND TELEVISION CORPORATION, PETITIONER,

vs.

HAZELTINE CORPORATION

ON WRIT OF CERTIORARI TO THE UNITED STATES CIRCUIT COURT OF APPEALS FOR THE SIXTH CIRCUIT

PETITION FOR CERTIORARI FILED DECEMBER 31, 1940.

CERTIORARI GRANTED FEBRUARY 3, 1941.

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PLAINTIFF'S EXHIBIT NO. 1

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VOLUME CONTROL

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Fig. 1

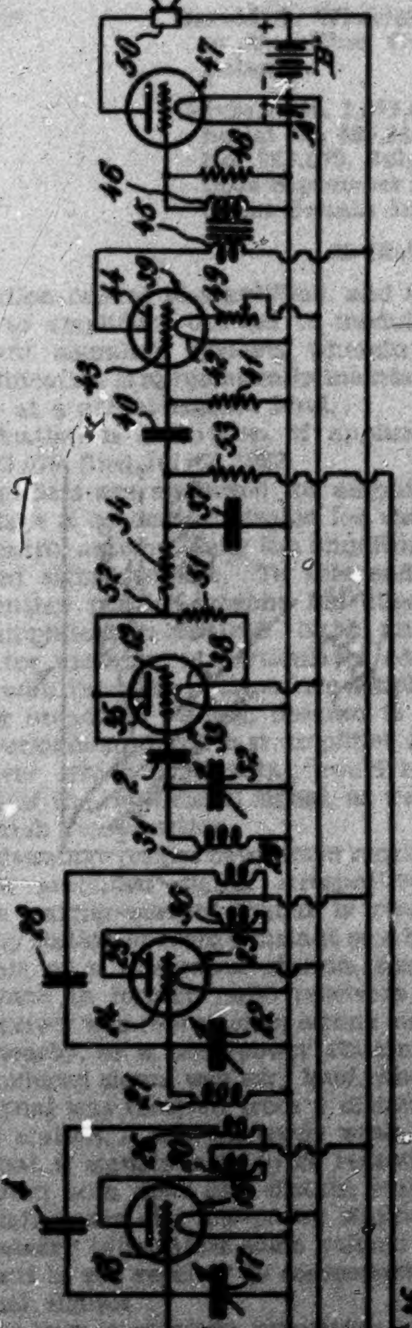
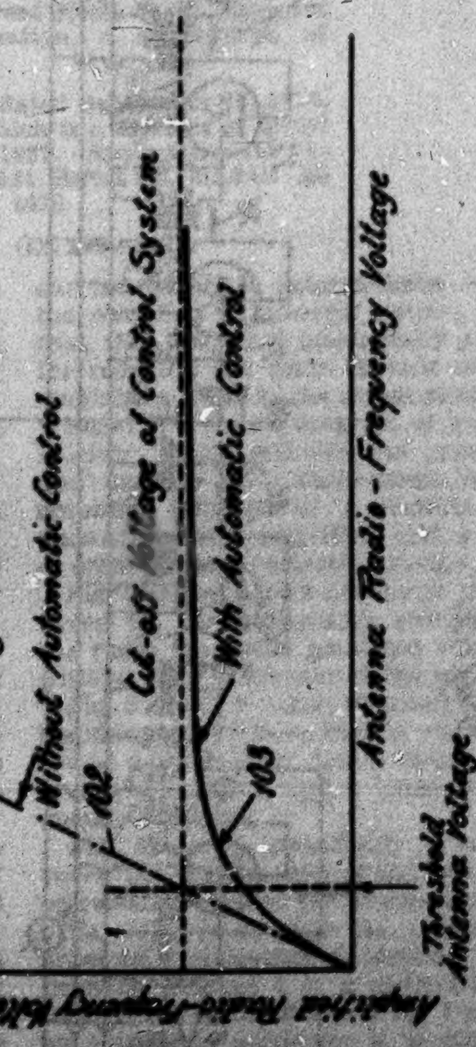


Fig. 2



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VOLUME CONTROL

Original Filed July 7, 1927 2 Sheets-Sheet 2

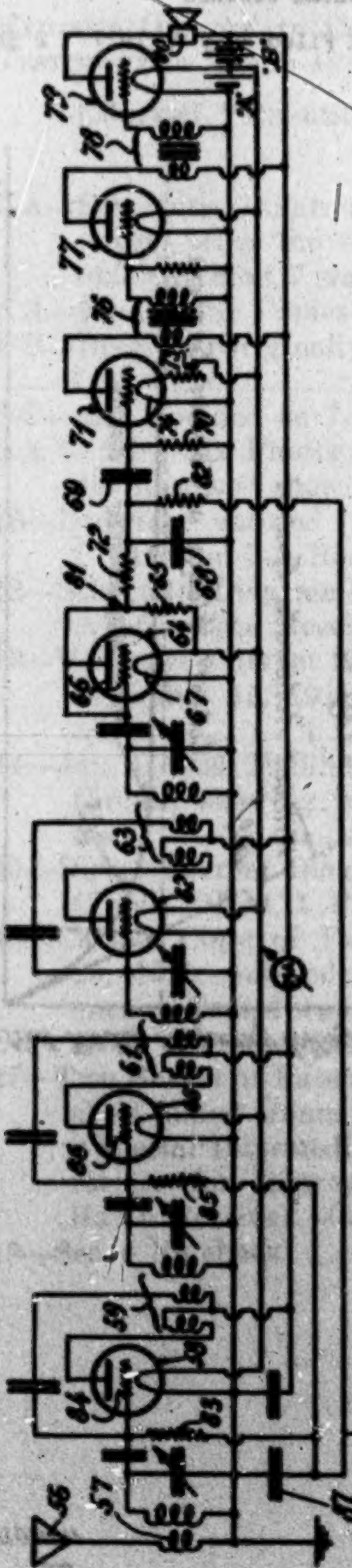

Fig. 3.

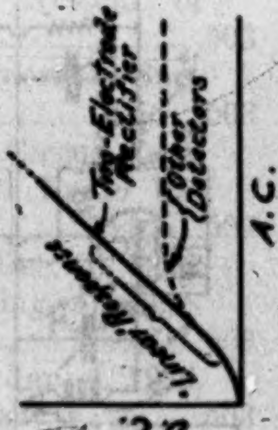

Fig. 4.

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UNITED STATES PATENT OFFICE

19,744

VOLUME CONTROL

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Original No. 1,879,863, dated September 27, 1932, Serial No. 495,384, which is a division of Serial No. 203,879, July 7, 1927. Application for reissue September 26, 1934, Serial No. 745,651. In Great Britain July 2, 1928

12 Claims. (Cl. 250—20)

This invention relates to amplifiers, and more particularly to amplifiers utilized in modulated carrier-current signaling systems wherein the limit of amplification is automatically maintained substantially at a predetermined level.

This application is a division of application Serial No. 203,879, filed July 7, 1927.

When amplifiers are employed for amplifying a signal voltage it becomes desirable for various reasons to control automatically the amplitude of this amplified signal voltage. To this end the present invention provides means for effecting automatic amplification control. Such an arrangement, for example, is particularly advantageous in radio receivers such as are employed for receiving broadcast signals, because it prevents the overloading of the last amplifier stage of the receiver, which overloading would result in distortion of the reproduced signal, as well as loud and harsh reproduction.

Another advantage resides in uniform reproduction of the amplified signal irrespective of whether the carrier-current signal is received from a nearby station or from a distant or a high-power station, or a low-power station, since it has been found in former radio receivers that when the receiver was reproducing strong signals as from a nearby, or a high-power station, the audibly reproduced signal was very loud, whereas when the signal was received from a distant, or a low-power station, it was relatively weak, with the result that if signals were to be reproduced uniformly from both near and distant stations, and from high-power and low-power stations, it became necessary to readjust some volume controlling means in the receiver to compensate for these unequal signals.

It has also been a common experience in the use of former radio receivers that the reproduced signal was not uniform due to the phenomenon of "fading", whereby the received signal occasionally, or periodically, became much weaker, or faded almost to the point of inaudibility. Since the present invention provides an amplifier which automatically compensates for inequalities in the received carrier-current signal strength, when "fading" takes place the degree of amplification is correspondingly increased and the reproduced signal maintained at its former volume, so that a listener is unaware that variation of the received carrier-current signal is occurring. This automatic compensation for signal fading is especially advantageous in commercial radio telephony and like systems.

A still further advantage is the saving in plate current which is automatically effected during the reception of powerful signals, for the reason that this invention incidentally provides means for reducing the plate current of one or more amplifying tubes as the signal strength increases.

Fig. 1 is a circuit diagram of a complete radio receiver which includes the present invention, and consists of a three-stage radio-frequency amplifier followed by a rectifier, a two-stage audio-frequency amplifier, and a loud speaker, or other suitable indicating device.

Fig. 2 shows curves disclosing the relation between the radio-frequency antenna voltage and the radio-frequency amplified voltage, with and without the application of the present invention.

Fig. 3 shows a circuit diagram of a second embodiment of the invention in which there is disclosed a three-stage tuned radio-frequency amplifier, a rectifier, and a three-stage audio-frequency amplifier.

Fig. 4 shows graphically a comparison between the performance of the two-electrode valve or rectifier, and of the three-electrode detector.

Referring in detail to Fig. 1, there is shown an antenna 5 connected to ground 4 through the primary winding 6 of a radio-frequency transformer, the secondary winding 7 of which, tuned by a variable condenser 8, is connected at one point to the filament 21 of the vacuum tube 9 in the first radio-frequency amplifying stage and at another point to the grid 11 of this vacuum tube. The output circuit of this vacuum tube extends from the filament system, through a high-voltage battery "B", a milliammeter 12, primary winding 13 of a second radio-frequency transformer to the anode or plate 14 of this vacuum tube. In order to neutralize the inherent capacity between the grid 11 and the plate 14, and thereby to prevent oscillations, and otherwise to increase the effectiveness of the present invention as hereinafter described, a neutralizing winding 19, electromagnetically coupled to winding 13, and a neutralizing condenser 3 are employed in the manner described in the U. S. patents to Hazeltine Nos. 1,450,080 and 1,533,858.

A second stage of radio-frequency amplification including the vacuum tube 15 neutralized by cooperation of coil 23 and condenser 4, like the first stage, comprises the secondary winding 16 of the last-mentioned radio-frequency transformer tuned by a variable condenser 17 connected between the filament system of the vacuum tube 15 and the grid 18 thereof. The output circuit of this vacuum tube also includes the high-voltage battery "B" and a primary winding 20

of a second radio-frequency transformer, while the secondary winding 21 of this transformer tuned by a variable condenser 22 is included in the input circuit of a third stage of radio-frequency amplification which includes vacuum tube 23. The inherent capacity effective between the electrodes 24 and 25 is neutralized by a network including the neutralizing condenser 26 and the neutralizing winding 28 as described in the mentioned patents. The output circuit of the vacuum tube 23 includes the primary winding 30 of a third radio-frequency transformer and the high-voltage battery "B". The secondary winding 31 of this last-mentioned transformer, tuned by a variable condenser 32, is connected in the input circuit of a rectifier 33 which input circuit includes the fixed condenser 2. The rectifier employed is a two-electrode rectifier which may be of the type commonly known in the art as a "Fleming" valve, or may consist of an equivalent such as a three-electrode vacuum tube, as shown, having its grid 12 and its plate or anode 35 directly connected together to comprise in effect a single anode.

It may here be noted that throughout the present specification and claims the terms "rectifier" and "detector" are, in general, used interchangeably, the terms "rectifying" and "converting" being employed in the general sense to include the process of changing alternating current into a form of direct current or modulated unidirectional current. Likewise, the terms "carrier-current" and "modulation current" may be substituted, respectively, for "radio-frequency current" and "audio-frequency current", since the description herein of radio-frequency amplifiers and audio-frequency amplifiers is merely by way of example of a typical embodiment of the present invention.

In the absence of the present invention including the control circuit 36, to be described, the three-stage tuned radio-frequency amplifier, including the vacuum tubes 8, 18 and 23, functions in a manner well-known in the art to amplify the incoming signal intercepted on the antenna 6. The output circuit of the rectifier 33 includes what may be termed a "rejector" circuit for stopping radio-frequency currents which have passed through the rectifier, and consists of a network including a resistance 34 and a by-pass condenser 37 connected between the anode 35 and the filament 38 of the rectifier. The output circuit of the rectifier is coupled to the input circuit of an audio-frequency amplifying vacuum tube 39 through an audio-frequency-pass filter including a fixed condenser 40 and a resistance 41 connected between the filament 42 and the grid 43 of this vacuum tube. As appears from the constants hereinafter given, the characteristics of this filter are such that it passes the audio-frequency component to the input circuit of the audio or modulation-frequency amplifier, while preventing the unidirectional component from being impressed upon the input circuit thereof. The output circuit of this amplifier is connected between the filament 42 and plate 44 through the high-voltage battery "B" and the primary winding 45 of an audio-frequency transformer, the secondary winding 46 of which is connected in the input circuit of a second audio-frequency tube 47, while a resistance 48 connected across the winding 46 serves to give the audio amplifier substantially uniform amplification over the desired frequency range. Instead of employing resistance 48, a closed copper band of suitable size may be placed around the transformer winding so as to be electromagnetically coupled thereto. A loud speaker or other reproducing device 50, or if required, a coupling device for a telephone system, is connected in the output circuit of the last audio-frequency amplifying tube 47. It is presumed that adequate precautions against undesired electromagnetic coupling between the various radio-frequency coupling transformers are included in all of the arrangements herein disclosed.

In accordance with the main feature of the present invention the degree of amplification effected in the radio-frequency amplifying stages is automatically controlled by a biasing potential obtained by rectifying the modulated signal carrier in a two-electrode rectifier 33, having a resistance 51 connected between the filament 38 and the anode 35 of the rectifier, through which the pulsating rectified or converted current flows, thereby developing a negative voltage at terminal 52. This negative voltage is applied over conductor 36 through the resistance 53 and the secondary winding 7 of the first radio-frequency transformer to grid 11 of the first radio-frequency stage. Resistance 53, together with blocking condenser 54, is effective to filter out and reject any audio-frequency voltages which otherwise might be applied from conductor 36 to the grid 11.

To complete the description of the system illustrated in Fig. 1 certain design data or constants are given herewith. It should be understood, however, that these, as well as all other constants appearing in the present specification, are mentioned merely by way of example in describing certain specific embodiments which in practice have proved eminently satisfactory and are not intended to suggest any specific limitations as to the scope of this invention. Accordingly, fixed condenser 2 may be of 0.0005 microfarad; 37 of 0.0001 microforad; 54 of 0.01 microfarad; 40 of 0.005 microfarad; resistance 51 of 1 megohm; 34 of 1 megohm; and 41 and 53 of 2 megohms each. The tubes may be assumed to be all of the well-known 201A type.

In the operation of the receiver shown in Fig. 1 a signal intercepted on the antenna 6 is successively amplified through the neutralized tuned radio-frequency stages indicated by the vacuum tubes 8, 18 and 23, connected in cascade. This amplified signal voltage is then rectified by the rectifier 33, and the rectified pulsating current is successively amplified by the audio amplifying stages including vacuum tubes 39 and 47, after which it may be reproduced as sound by the loud speaker 50.

The high resistance 51 connected between the filament 38 and the anode 35 of the rectifier, through which a small space current flows in the absence of signal output from the radio-frequency amplifier, maintains the anode normally negative relative to at least part of the filament of the rectifier. Since all the filaments are connected in parallel, the rectifier filament is maintained at substantially the same potential as the filament 27 of the first radio-frequency amplifier tube 8. Therefore the resistance 51 is connected effectively between the rectifier anode 35 and the amplifier filament 27, and thereby maintains the rectifier anode normally negative relative to at least part of the amplifier filament.

When the rectified or converted signal current (or space current) flowing through the space current circuit including resistance 51 increases with

signal output beyond a predetermined value, there is developed at the anode terminal 52 sufficient increase of negative biasing voltage, which in turn is impressed, through the direct-current connection including conductor 38, upon the grid 11 of the vacuum tube 9, to reduce the amplification of this tube. Conversely, it will be apparent that as the magnitude of the rectified current flowing through resistance 51 decreases with decreasing signal strength, the voltage at terminal 52 becomes less negative, and the negative biasing voltage impressed upon the grid 11 also diminishes so that the vacuum tube 9 effects an increased degree of amplification. In this manner, the radio-frequency voltage applied to the input of the rectifier is maintained at a nearly constant predetermined value, and the volume of the reproduced signal is substantially uniform under all conditions. The level at which the volume is maintained uniform is determined by adjustment of rheostat 40 which controls the heating current in the filament 42 of the first audio-frequency amplifying tube 39.

In the above operation it is noted that the two-electrode rectifier 33 functions as the signal detector and also effects rectification of the modulated radio-frequency carrier current to control amplification in the first radio-frequency stage of the receiver. The audio-frequency component of the detector output is transferred to the input circuit of the audio-frequency amplifier for further amplification.

The neutralization of the grid-plate capacity of the radio-frequency amplifying tubes is, in combination with the present invention, particularly valuable in that it allows an increase in the effectiveness of the amplification control, because such neutralization prevents radio-frequency energy from passing through the grid-plate capacity of the tubes. Thus the relay action of the tubes is almost entirely subject to the control by grid bias voltage provided in accordance with this invention.

The time required for operation of the control system would ordinarily be determined by the lowest audio-frequency modulation which must be reproduced. Fading, for example, might be considered a form of modulation; the frequency of the rise and fall of signals due to fading being the frequency of modulation. If this frequency of modulation be increased sufficiently, the effect will be audio-frequency modulation. It will thus be seen that if the automatic control attained by the present invention be allowed to respond too quickly, it will tend to smooth out the desired modulation of the signals at the lower audio frequencies. Hence, a time constant of operation is chosen which will be greater than the period of the audio frequencies which the system is intended to amplify. This time constant of the control circuit is equal to the product of the series resistance and the shunt capacitance of the grid bias circuit, represented in Fig. 1 by resistance 53 between conductor 38 and the anode terminal 52, in the direct-current connection back to the grid 11, and condenser 54 connected between the amplifier filament 27 and a point on conductor 38. Since the time constant can always be reduced to a value equal to the period of the lowest modulation frequency, it may readily be set to meet the requirements of nearly any special case which may arise. For example, a value of two million ohms resistance and of 0.1 microfarad capacitance gives a time constant of one-fifth of a second, which does not appreciably affect the modulation of frequencies above five cycles. While this constant is greater than required from the point of view of satisfactory audio-frequency quality in the reproduction of music, there appears to be no need for more rapid control under the conditions usually encountered. The use in this connection of condensers of large capacitance, such as one-tenth microfarad, likewise introduces another convenience in that the condensers may also serve to by-pass radio frequencies in order to prevent undesired coupling between the detector circuit and the first radio-frequency amplifying tube because of some impedances common to those two portions of the apparatus.

The milliammeter 10 is connected in the anode circuit of the amplifying vacuum tube 9. Upon receipt of an amplified signal at the rectifier, the effect of the control circuit is to decrease the plate current through milliammeter 10, thereby reducing the amplification in the tube 9. When the receiver is tuned to the signal frequency, a minimum amplification is required, so that when the condition of resonance is attained, the plate current of tube 9 is at a minimum value, and the milliammeter 10 so indicates. Thus the milliammeter visually indicates the condition of resonance.

For a better understanding of the present invention reference is made to Fig. 2. It will be appreciated that in a system similar to that illustrated in Fig. 1, but in which no means for automatically limiting the degree of amplification is included, the amplified radio-frequency voltage is proportional to the radio-frequency antenna voltage, as indicated by curve 102. When, however, the present invention is employed in such an amplifier, the relation between the radio-frequency antenna voltage and the amplified radio-frequency voltage is indicated by curve 103 from which it will be seen that when at least a certain predetermined radio-frequency antenna voltage is present, (herein referred to as the "threshold antenna voltage") the amplified radio-frequency voltage approaches—but is always less than—another certain predetermined voltage value (herein referred to as the "cut-off voltage").

The modification illustrated in Fig. 3 is an especially desirable form of the present invention, and includes antenna 56, connected by means of a transformer 57 to a neutralized three stage tuned radio-frequency cascade amplifier including the vacuum tubes 58, 60 and 62 coupled by transformers 59 and 61. The last stage of the amplifier is connected by a transformer 63 to a two-electrode rectifier 64 of the type already described, the output circuit of which, including the resistance 65, is connected between the anode 66 and filament 67 of the rectifier, as previously explained. Resistance 72 and condenser 68 associated with this output circuit, constitute a "rejector" network which filters out the radio-frequency current component in the output circuit of the rectifier 64, while the network including condenser 69 and resistance 70 constitutes an audio-frequency-pass filter for coupling the output circuit of the rectifier to the input circuit of the audio-frequency amplifier which includes vacuum tube 71. Rheostat 73 controls the heating current supplied to the filament 74 of this vacuum tube, and thereby permits a manual adjustment of the volume of the reproduced signal desired by the listener. Audio-frequency transformer 75, which is preferably of a low ratio of transformation, couples the output circuit of vacuum tube 71 to a

second audio-frequency amplifying tube 77. This last vacuum tube in turn is coupled by a second audio-frequency transformer 78 to a third audio-frequency amplifying tube 79 in the output circuit of which there is included a loud speaker 80.

In this arrangement automatic amplification control is effected in a manner slightly different from that shown in the diagram of Fig. 1, since in this instance the radio-frequency voltage of the signals intercepted by the antenna 55 is successively amplified by three neutralized tuned radio-frequency amplifying stages including the vacuum tubes 58, 60 and 62, of which two (instead of one) are controlled in accordance with the present invention. The amplified radio-frequency current is rectified by the rectifying valve 64, and successively amplified at audio-frequency by the vacuum tubes 71, 77 and 79. The rectified current in the output circuit of the rectifier flows through the resistance 65, and thereby develops a negative voltage at the terminal 81, which voltage is applied through the resistances 72, 82, 83 and 85 to the grids 84 and 86 of the radio-frequency amplifying tubes 58 and 60. By thus simultaneously controlling the degree of amplification of two successive radio-frequency amplifying stages a greatly increased uniformity of regulation is attained. Resistance 82 and the condenser 87 constitute an audio-frequency-stop filter, so that substantially only direct-voltage is impressed upon the grids 84 and 86. It will be understood that the voltage developed at terminal 81 is a function of the amplified radio-frequency voltage delivered to the input circuit of the rectifier by the radio-frequency amplifying tubes 58, 60 and 62, and therefore, as the negative voltage at terminal 81 tends to increase with the increased signal, the resulting increase of biasing voltage impressed upon the grids of the tubes 58 and 60 limits the degree of amplification effected in the radio-frequency stages including those tubes.

In this arrangement the constants for the various resistances and condensers may, for example, be the same as those for the corresponding elements in Fig. 1. In addition the grid resistances 83 and 85 may have a value of 2 megohms each; and the grid condensers connected at the junctions of these resistances and the grid electrodes 84 and 86 may each be of 0.001 microfarad capacity.

In Figs. 1 and 3 the variable tuning condensers are grounded in order to eliminate undesirable capacity effects as well as to make it practicable to connect the condensers on a single shaft for uni-control, if desired.

There are advantages attending the use, in connection with the present invention, of the two-electrode rectifier circuit typified by Figs. 1 and 3, which may not be apparent from the foregoing discussion. It is impossible to overload this type of rectifier, and the rectified output voltage is directly proportional to the applied alternating signal voltage when this voltage is large, say over two volts. The control system in the circuits of the figures referred to requires a large operating voltage, say ten volts, so that the latter condition of large signal voltage is realized. No such simple relationship is possible in a three-electrode detector, whose rectified output never exceeds a limiting upper value, and is never proportional to the applied voltage, except over a very small range of voltages. This distinction will be seen from Fig. 4 where the abscissae "A. C." represent the alternating signal voltages, whereas the ordinates "D. C." represent the rectified output voltages. It is well known that the linear curve is much more desirable when minimum distortion of a modulated signal is desired, and it will be observed from Fig. 4 that the preferred type of curve is obtained from the two-electrode rectifier.

If a three-electrode detector were used in an automatic amplification control system, the rectified output voltage would be approximately proportional to the square of the applied voltage, i. e., to the power associated with the applied voltage. For this reason the rectified voltage would increase with the carrier wave modulation. Therefore, if such a detector were so used the total power from the radio-frequency amplifier would be maintained at a substantially constant level, the amplitude of the carrier wave being decreased in the presence of modulation. It is desirable to maintain the carrier wave at a constant amplitude at the output of the amplifier, and this is accomplished by the two-electrode rectifier as shown in Figs. 1 and 3. The control system maintains constant the average signal amplitude which is equal to the carrier wave amplitude and independent of the degree of modulation.

It will be observed that in a system employing a two-electrode rectifier such as represented by tube 33 of Fig. 1, and 64 of Fig. 3, the control bias voltage is independent of the "B" or anode battery voltage. Since the rectifier is not an amplifier, is not critical, and requires neither anode nor biasing battery, no adjusting devices are required. This is not the case in three-electrode detector circuits in which an adjustment must be made, as by a potentiometer, to accommodate the control bias to any particular combination of tubes and "B" voltage.

In the foregoing description, tuned radio-frequency receivers of the neutralized type have been referred to. It should be pointed out, however, that the present invention is generally applicable to radio receivers in wired radio and space radio systems, and that it has been found especially applicable to receivers of the super-heterodyne type.

It is well-known that the common "B" battery may be replaced by a source of rectified and filtered alternating current, and, in the event that tubes having indirectly heated cathodes are used instead of those having incandescent filament cathodes, the common "A" battery may be replaced by a source of alternating current.

For these reasons the present disclosure of typical embodiments of the invention should not be construed as a limitation, but merely as illustrative of the principles of the invention, the scope of which is defined in the appended claims.

What is claimed is:

1. In a signal receiver having a carrier-frequency amplifier which includes at least one vacuum tube having a cathode and a control electrode, a two-electrode rectifier coupled to the output circuit of said amplifier, a high resistance connected between the rectifier anode and the amplifier cathode, means including said resistance for maintaining the average potential of said anode normally negative relative to at least part of said amplifier cathode and increasingly negative with increasing amplified signal output from said amplifier, and a direct-current connection from said anode back to said amplifier control electrode whereby the amplification of said amplifier is regulated automatically.

2. In a carrier-current signaling system, in

combination, a vacuum tube amplifier having a cathode and a control electrode, a vacuum tube detector coupled directly to the output of said amplifier, said detector having a cathode and an output electrode, means for maintaining said detector cathode at substantially the same potential as said amplifier cathode, means for maintaining said output electrode at a negative potential with respect to said cathodes, means causing said output electrode to become more negative in the presence of an amplified signal, and a direct-current connection between said output electrode and said control electrode.

3. A combination according to claim 2 in which the means for maintaining the detector output electrode at a negative potential with respect to said cathodes is a resistance connected between said output electrode and the detector cathode.

4. In a modulated-carrier signal receiver having a carrier-frequency amplifier, a two-electrode rectifier coupled to the output circuit of said amplifier, which rectifier produces a modulated unidirectional voltage, a direct-current connection from said rectifier to an element of said amplifier whereby the amplification is regulated automatically, and a connection from said rectifier to a modulation-frequency amplifier whereby the signal is further amplified, said connection from said rectifier to said modulation-frequency amplifier including a condenser in series for preventing the uni-directional component from being impressed upon the input of said modulation-frequency amplifier.

5. In a signaling system, a vacuum tube amplifier having a cathode and a control electrode, a diode detector coupled to said amplifier, said detector having a cathode and an anode, means for maintaining said cathodes at substantially the same potential, means including a high resistance connected between the detector anode and cathode for maintaining said anode normally slightly negative relative to said cathodes, means for causing said anode to become more negative in the presence of an amplified signal, and a direct-current connection between said control electrode and said anode, whereby the amplification of said amplifier is regulated automatically.

6. In a modulated-carrier signal receiver having a carrier-frequency amplifier adapted to amplify modulated signals prior to detection, which amplifier has means for tuning to a desired signal and includes at least one amplifier vacuum tube having a cathode and a control electrode and possessing the property that its amplification decreases with increasingly negative biasing potential on said control electrode relative to the cathode; a system of automatic amplification control which includes a second vacuum tube coupled to the output circuit of the amplifier by means no more selective than the amplifier, said second vacuum tube having an output electrode, means for maintaining the average potential of said output electrode normally slightly negative relative to at least part of said amplifier cathode and increasingly negative with increasing amplified signal output from said amplifier, a direct-current connection from said output electrode back to the amplifier control electrode for impressing thereon a negative biasing potential which varies in accordance with the average potential of said output electrode, whereby the carrier-frequency amplification in said amplifier is substantially decreased automatically with increasing amplified signal output from said amplifier, and a visual indicator coupled to the output circuit of the amplifier and responsive to the relative magnitude of said output, whereby the visual indication follows the strength of the detected signal and thereby facilitates tuning.

7. In a modulated-carrier signal receiver having a carrier-frequency amplifier adapted to amplify modulated signals prior to detection, which amplifier has means for tuning to a desired signal and includes at least one amplifier vacuum tube having a cathode and a control electrode and possessing the property that its amplification decreases with increasingly negative biasing potential on said control electrode relative to the cathode; a system of automatic amplification control which includes a two-electrode rectifier coupled to the output circuit of the amplifier by means no more selective than the amplifier, a high resistance connected between the rectifier anode and said amplifier cathode, means including said resistance for maintaining the average potential of said anode normally negative relative to at least part of said amplifier cathode and increasingly negative with increasing amplified signal output from said amplifier, a direct-current connection from said anode back to said amplifier control electrode for impressing thereon a negative potential which varies in accordance with the average potential of said anode, whereby the carrier-frequency amplification in said amplifier is substantially decreased automatically with increasing amplified signal output from said amplifier, and a visual indicator coupled to the output circuit of the amplifier and responsive to the relative magnitude of said output, whereby the visual indication follows the strength of the detected signal and thereby facilitates tuning.

8. An arrangement according to claim 7 in which said visual indicator is connected in the anode circuit of said amplifier vacuum tube.

9. In a modulated-carrier signal receiver having a carrier-frequency amplifier adapted to amplify modulated signals prior to detection, which amplifier has means for tuning to a desired signal and includes at least one amplifier vacuum tube having a cathode and a control electrode and possessing the property that its amplification decreases with increasingly negative biasing potential on said control electrode relative to the cathode; a system of automatic amplification control which includes a second vacuum tube coupled to the output circuit of the amplifier by means no more selective than the amplifier, said second vacuum tube having an output electrode whose space current circuit includes resistance connected between said output electrode and said amplifier cathode, means including said resistance for maintaining the average potential of said output electrode normally negative relative to at least part of said amplifier cathode and increasingly negative with increasing amplified signal output from said amplifier, a direct-current connection from said output electrode back to said amplifier control electrode for impressing thereon a negative biasing potential which varies in accordance with the average potential of said output electrode, a condenser connected between said amplifier cathode and a point on said direct-current connection, and resistance in said direct-current connection between said point and said output electrode which with said condenser provides a time constant predetermined to filter out voltage fluctuations at frequencies of signal modulation, whereby the carrier-frequency amplification in said amplifier is substantially decreased automatically with increasing amplified signal output

from said amplifier and the detected signal strength is automatically controlled irrespective of whether the amplifier is exactly in tune with the signal carrier.

10. In a modulation-carrier signal receiver having a carrier-frequency amplifier adapted to amplify modulated signals prior to detection, which amplifier has means for tuning to a desired signal and includes at least one amplifier vacuum tube having a cathode and a control electrode and possessing the property that its amplification decreases with increasingly negative biasing potential on said control electrode relative to the cathode; a system of automatic amplification control which includes a two-electrode rectifier coupled to the output circuit of the amplifier by means no more selective than the amplifier, a high resistance connected between the rectifier anode and said amplifier cathode, means including said resistance for maintaining the average potential of said anode normally negative relative to at least part of said amplifier cathode and increasingly negative with increasing amplified signal output from said amplifier, a direct-current connection from said anode back to said amplifier control electrode for impressing thereon a negative biasing potential which varies in accordance with the average potential of said anode, a condenser connected between said amplifier cathode and a point on said direct-current connection, and resistance in said direct-current connection between said point and said anode which with said condenser provides a time constant predetermined to filter out voltage fluctuations at frequencies of signal modulation, whereby the carrier-frequency amplification in said amplifier is substantially decreased automatically with increasing amplified signal output from said amplifier and the detected signal strength is automatically controlled irrespective of whether the amplifier is exactly in tune with the signal carrier.

11. In a modulated-carrier signal receiver having a carrier-frequency amplifier which includes at least one amplifier vacuum tube having a cathode and a control electrode and possessing the property that its amplification decreases with increasingly negative biasing potential on said control electrode relative to the cathode; a system of automatic amplification control which includes a two-electrode rectifier coupled to the output circuit of the amplifier, a high resistance connected between the rectifier anode and said amplifier cathode, means including said resistance for maintaining the average potential of said anode normally negative relative to at least part of said amplifier cathode and increasingly negative with increasing amplified signal output from said amplifier, a direct-current connection from said anode back to said amplifier control electrode for impressing thereon a negative biasing potential which varies in accordance with the average potential of said anode, a condenser connected between said amplifier cathode and a point on said direct-current connection, and resistance in said direct-current connection between said point and said anode which with said condenser provides a time constant predetermined to filter out voltage fluctuations at frequencies of signal modulation, whereby the carrier-frequency amplification in said amplifier is substantially decreased automatically with increasing amplified signal output from said amplifier.

12. In a modulated-carrier signal receiver having a carrier-frequency amplifier which includes at least one amplifier vacuum tube having a cathode and a control electrode and possessing the property that its amplification decreases with increasingly negative biasing potential on said control electrode relative to the cathode; a system of automatic amplification control which includes a two-electrode rectifier coupled to the output circuit of the amplifier, means for maintaining the amplifier and rectifier cathodes at substantially the same potential, a high resistance connected between the anode and the cathode of the rectifier, means including said resistance for maintaining the average potential of said anode normally negative relative to at least part of said amplifier cathode and increasingly negative with increasing amplified signal output from said amplifier, a direct-current connection from said anode back to said amplifier control electrode for impressing thereon a negative biasing potential which varies in accordance with the average potential of said anode, a condenser connected between said amplifier cathode and a point on said direct-current connection, and resistance in said direct-current connection between said point and said anode which with said condenser provides a time constant predetermined to filter out voltage fluctuations at frequencies of signal modulation, whereby the carrier-frequency amplification in said amplifier is substantially decreased automatically with increasing amplified signal output from said amplifier.

13. In a modulated-carrier signal receiver having a carrier-frequency amplifier which includes at least one amplifier vacuum tube having a cathode and a control electrode and possessing the property that its amplification decreases with increasingly negative biasing potential on said control electrode relative to the cathode, said receiver also having a modulation-frequency amplifier which is coupled to a signal reproducer; a system of automatic amplification control which includes a two-electrode rectifier coupled to the output circuit of the carrier-frequency amplifier, a high resistance connected between the rectifier anode and said amplifier cathode, means including said resistance for maintaining the average potential of said anode normally negative relative to at least part of said amplifier cathode and increasingly negative with increasing amplified signal output from said carrier-frequency amplifier, a direct-current connection from said anode back to said amplifier control electrode for impressing thereon a negative biasing potential which varies in accordance with the average potential of said anode, a condenser connected between said amplifier cathode and a point on said direct-current connection, resistance in said direct-current connection between said point and said anode which with said condenser provides a time constant predetermined to filter out voltage fluctuations at frequencies of signal modulation, whereby the carrier-frequency amplification is substantially decreased automatically with increasing amplified signal output from said carrier-frequency amplifier, a modulation-frequency connection from said anode to the modulation-frequency amplifier, whereby the rectifier serves also for signal detection, and manually adjustable means for determining the modulation-frequency amplification, whereby the reproduced signal is maintained substantially at any desired volume.

HAROLD A. WHEELER.

PLAINTIFF'S EXHIBIT NO. 2A

This Booklet Contains Instructions for Installation Operation and Servicing

SUPERHETERODYNE RADIO RECEIVER

WITH

ELECTRIC TUNING

FACTORY **175** SERIES

PLEASE READ CAREFULLY

[illegible] PART NO. [illegible]

SUPERHETERODYNE SERIES 175

This book of instructions is published for the purpose of assisting in the installation and operation of your receiver in order that the excellent performance of which it is capable may be fully realized. May we suggest that you read the instructions carefully before attempting to receive stations, and follow the installation procedure exactly as outlined below. While locations and functions of the controls have been arranged so as to simplify their use, careful study of the detailed information contained in this book will enable even the most inexperienced operator to secure satisfactory results.

WARRANTY

This receiver with tubes was carefully tested, inspected and packed in an approved shipping container and left our factory in perfect operating condition. Should any damage occur while in transit, file claim with carrier at once.

We warrant this receiver to be free from defect in material and workmanship and to give satisfactory performance under normal use. Our obligation under this warranty is limited to making good at our factory any part or parts thereof which shall, within the 90 days from the date of purchase, be returned to our factory, carefully packed and transportation charges prepaid.

This warranty does not apply if, in our judgment, this set has been mis-used, abused or connected otherwise than in accordance with the following instructions. Should this receiver become inoperative within the warranty period, it should be returned for service to the dealer from whom it was purchased.

PREPARING THE RECEIVER

Carefully remove the receiver from the packing carton and check mechanical condition (see warranty).

Remove all packing, clips, and bands from around the tubes and power cord. Do not remove any special instruction tags or cards attached to the set or cabinet until all persons likely to operate the set are thoroughly familiar with the information printed on the cards. Tags, cards, and stickers fastened to the inside of the cabinet or on the chassis should never be removed; their purpose is to assist in making the original installation and to simply tube changing, checking connections, and so forth when such is found to be necessary at some later date.

POWER SUPPLY

Unless specifically stated otherwise, these receivers are designed to operate on *115 volts 60 cycles alternating current only.* Do not connect the power cord to any receptacle until it has been made certain that the voltage and frequency of the power available is the same as that called for on the license plate on the rear of the receiver chassis. A telephone call to the local power company will eliminate all doubt as to the nature of the power supply.

ANTENNA

For best results, it is recommended that a good outdoor antenna be installed. Do not use an old antenna as most of the older installations were not intended for reception of short waves, and many are not suitable for good broadcast reception.

The average length of a single wire antenna, including lead-in, should be not less than fifty feet. In locations near powerful broadcast stations, this length may be shortened to thirty-five feet. In more favorable locations, seventy-five feet should be used.

Regardless of its length, the antenna and lead-in should be spaced well away from the roof, sides of the building, trees, and power lines. Stand-off insulators should be used to hold the lead-in wire at least six inches from the building, and the lead should be brought into the building through a porcelain tube insulator. The receiver should be located as near to the point where the lead-in is brought through the wall as is conveniently possible.

Indoor antennae will give good broadcast reception except in steel frame buildings. However, foreign reception will not be satisfactory unless an outdoor antenna is provided.

When a lightning arrestor is used, it must be of a special low-capacity type so that foreign reception will not be impaired.

GROUND

While not absolutely necessary for ordinary operation of the receiver, it is recommended that a ground connection be made. A cold-water pipe, scraped free of dirt and corrosion, makes a good ground; if more convenient a connection to a steam pipe will do. The ground lead should be short, and must be secured to the pipe by soldering or by means of a ground clamp. Proper grounding will very often eliminate objectionable noises.

Where neither of the above types of grounds are available, a length of galvanized pipe driven a few feet into moist earth will be sufficient.

TUBES

Tubes required are:

1—6A7 Oscillator-translator
1—6D6 Intermediate Frequency Amplifier
1—75 Detector AVC—First Audio Amplifier
1—76 Driver—Phase Inverter
2—42 Power Output
1—80 Rectifier
1—6G5 Cathode Ray Tuning Tube (on models equipped with "eye" tuning indicator)

Do not use tubes of types different from those shown above. When replacing tubes or checking connections, refer to the *Tube Layout Chart.*

CONNECTIONS

Turn the lower left knob to the left as far as it will go. This turns the power switch "off."
Connect the antenna and ground leads to the receiver as shown on the diagram on Page 7.
Insert the power supply plug into a convenient receptacle. The receiver is now ready for operation.

OPERATION

CONTROLS

There are four control knobs on the front of the cabinet. The upper left knob is the ***Tone Control,*** the the upper right is the ***Station Selector,*** the lower right knob is the ***Band Selector Switch,*** and the lower left is the ***On-Off Switch and Volume Control.***

Operation of the controls is as follows:

On-Off Switch and Volume Control: Turning the control toward the right increases the volume or loudness, turning toward the left decreases the volume. The extreme left position turns the power off.

Station Selector: The various stations are tuned in by rotating the knob so that the pointer moves across the dial. To insure proper tuning, always rotate the pointer about one-half division beyond the desired station, then move the knob back and forth so as to tune through the signal until best reproduction is obtained. Perfect tuning will be indicated by the Cathode Ray tube when the shadow on the screen has the least width. For operating information on ***Automatic Tuning,*** see pages 4 and 5.

Band Selector Switch: Standard broadcast stations operating on frequencies between 540 and 1600 kilocycles will be received when this switch is in the extreme left position. The letter "B" on the switch knob should be opposite the indicator pin.

Police, amateur, aviation, and foreign stations operating on frequencies between 1650 and 5400 kilocycles will be received when the knob is set in the center position so that the letter "P" appears opposite the marker pin.

Turning the switch all the way to the right so that the letter "F" is opposite the marker pin connects the circuits for reception of foreign and domestic shortwave broadcasts, ships, and amateurs operating on frequencies between 5400 and 16,000 kilocycles.

For further information as to nature of stations on the various bands, see the following paragraphs devoted to descriptions in detail.

The Band Selector Switch should always be turned to the extreme left position except when receiving short-wave stations.

Tone Control: Turning this knob to the right increases the high note response, turning to the left emphasizes the low notes. The bass position, all the way to the left, reduces noise on weak stations.

Tuning Indicator: On models equipped with the cathode tuning tube, resonance is indicated by variation in the width of the shadow in the lower half of the screen. For perfect tuning, rotate the station selector knob back and forth through the desired station until the tuning tube shadow is closed, or until the shadow has the least width. On very strong stations, the shadow may disappear entirely or the sides may overlap slightly.

TO RECEIVE STANDARD BROADCAST STATIONS

Turn the lower left hand knob to the right to the point where the switch snaps on and the dial becomes illuminated. It will be necessary to wait about one minute for the tubes to become heated before tuning stations. See that the volume control is turned to within a few degrees of its extreme left position, and make sure that the band selector switch is in the "B" position.

After the tubes have reached their operating temperature, rotate the station selector knob until a station is heard, then tune in according to the procedure outlined for use of the station selector and tuning indicator. With the station tuned in perfectly, adjust the volume control to give the desired degree of loudness; once the control has been set, the ***Automatic Volume Control*** will tend to maintain the same level when other stations are tuned in, or when a particular station "fades." ***Do not adjust volume by shifting the Station Selector—use the Volume Control.*** Do not tune at high volume settings.

After the station has been properly tuned in, the tone should be adjusted to suit the type of program being received. Rotating the ***Tone Control*** knob to the right makes the tone more brilliant; to the left emphasizes the low notes. In general, the brilliant position is most desirable for speech or high output conditions, and the bass position is best for some types of music and for general reception at low volume levels. When listening to most types of band or orchestral music, a position for this control, a few degrees from the bass position, will be found where high notes are still present and the low notes are emphasized. This position gives an effective ***"Low Note Boost,"*** and aids materially in obtaining realistic reproduction.

TO RECEIVE SHORT-WAVE STATIONS

Turn the band selector switch to "P" or "F," depending upon the type reception desired (see paragraph titled ***"Band Selector"***). The same general directions as for tuning broadcast stations should be followed. Tuning on these bands must be done more slowly and carefully than tuning the broadcast band, and particular attention must be paid as the pointer moves over the portions of the dial marked "Police," "Foreign," etc., as most of the points affording desirable reception are so marked.

It will be noticed that "fading" is much more pronounced on these bands. Unless the pointer is moved very slowly, many stations will be missed completley due to passing by them while they are faded out. It is best to advance the pointer about one division at a time, rocking the knob slowly back and forth as the pointer is moved ahead.

In general, the high frequency end of the foreign band will afford the best reception during the early morning hours, and the low frequency end will be the best at night. Occasions will be found when this rule does not hold exactly, but ordinarily the higher frequencies will not be heard except during periods when daylight exists between the station and the receiver, and the lower frequencies will only be heard when it is dark at transmitter and receiver. For example, during most of the year, London will be heard on the 17.8 mc and 15.2 mc bands before 10 A. M. (EST), at noon the 11.8 mc band, on the 9.6 mc band around 4 P. M., and on the 6.0 mc band at night. During the summer months the higher frequencies are better at night, good reception on the 11.8 mc European stations often is had as late as midnight.

An important feature of the short-wave bands is that coast-to-coast reception of domestic stations is possible during the day time. New York programs may be heard in most Southwestern and Western states at practically any time of the day by tuning the proper band. However, nearby stations may not be heard at all due to the "skip" effect.

Interference from "man-made" static is worse on short waves than on regular broadcast. Noises from appliances, motors, automobile ignition systems, and other similar sources are considerably more noticeable. On the other hand, natural static is not as bad on the higher frequencies, noise-free reception often being possible during a thunder-storm.

Short wave reception will be greatly simplified if full use is made of the information furnished with the receiver, in conjunction with that published in newspapers and radio magazines. Knowledge of station and schedule changes, reception conditions, etc., will aid materially in securing favorable results. It is recommended that information pertaining to these factors be kept up-to-date by obtaining new log books or guides at regular intervals.

READING THE DIAL SCALES

The broadcast band is calibrated in kilocycles. Refer to log book charts for station call letters, frequencies, power and geographical location. Newspaper program guides furnish similar information concerning popular stations in their general locality.

The lower outside scale is the foreign band; the scale nearest the center is the police band. The upper half of the police band scale is calibrated in megacycles; the lower half lists the various services at the points where they may be received.

The foreign band is calibrated in megacycles (1 megacycle = 1,000 kilocycles). All the prominent services are listed at the points where they may be received.

TUNING SUGGESTIONS

Do not regulate volume by de-tuning—use the volume control.

Do not attempt to tune broadcast stations with the receiver set for short-wave reception.

Satisfactory reception from distant standard broadcast stations may be had only at night.

Amateur stations have no definite frequency assignment other than their band assignment. As a result, much interference between stations will be heard at times, on their bands.

Distant stations cannot be received on channels assigned to a number of stations, except under unusual conditions.

Do not expect consistent foreign reception. Signals may be received well for several days, then suddenly drop to a very low level for a while.

SERVICE SUGGESTIONS

Be sure that antenna and ground connections are made according to instructions.

See that all tubes are in the proper sockets, that they are in good operating condition, and that clips are attached to the small caps on tops of those tubes requiring them. Make sure that the tube shields are not shorting the clips to the chassis.

Be sure that the Band Selector Switch is in the proper position for the type of reception desired.

See that all plugs are making proper contact. *(See Installation Notes.)*

If the receiver remains inoperative after the above suggestions have been tried, *turn the Power Switch "Off."* Never leave the switch turned on when signs of abnormal heating are present. A minor circuit trouble may cause an expensive repair bill if the set is allowed to run for any length of time after the trouble develops.

Occasionally a loud hum will be heard as stations are tuned in. Reverse the power supply plug. If the hum persists, remove the cause by properly grounding other sets or appliances in the house.

LICENSE NOTICE

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RADIO CORPORATION OF AMERICA
GENERAL ELECTRIC COMPANY
WESTINGHOUSE ELECTRIC & MFG. CO.

and associated companies, only for radio amateur, experimental and broadcast reception.

1,128,292	1,231,764	1,385,873	1,493,595	1,618,017
1,129,942	1,251,377	1,387,984	1,504,537	1,622,170
1,158,123	1,273,627	1,426,754	1,520,994	1,626,391
1,173,079	1,313,094	1,459,412	1,537,708	1,631,646
1,195,632	1,349,252	1,465,332	1,558,437	1,707,617
1,201,272	1,377,405	1,483,273	1,573,374	1,728,879

INSTRUCTIONS FOR ADJUSTMENT AND OPERATION OF THE ELECTRIC AUTOMATIC TUNING SYSTEM

Before attempting to adjust the automatic tuner, read the following instructions carefully and proceed exactly as directed. Setting up the *Master Selector* requires no tools, and is very easily accomplished when the proper procedure is followed.

The tuning unit consists essentially of three parts, which may be described briefly as follows:

Master Selector: This includes the *Selector Drum*, the *Selector Pins*, and the *Selector Light*. These parts are mounted on the rear of the variable condenser, together with their associated brackets and wiring.

Motor and Drive: This assembly consists of an induction motor having a mechanical drive clutch with magnetic throw-out, and a train of gears operating directly onto the *Manual Station Selector* drive shaft. No oiling is necessary.

Push Button Assembly: These buttons are located on the front of the chassis, and extend through the escutcheon below the dial. Stations are tuned in automatically when the button under the call letters of the desired station is depressed and held down until the motor stops and the station is heard. When the button is pushed down, an automatic silencer mutes the receiver until the desired station is exactly on tune.

SETTING UP THE MASTER SELECTOR

As a means of simplifying these operations, list eight of your favorite *local* or strong near-by stations according to frequency or position on the dial. Setting up weak or distant stations is not recommended. Call the station nearest the left-hand end of the dial (nearest 1600 kc) the *No. 1* station, and number the other

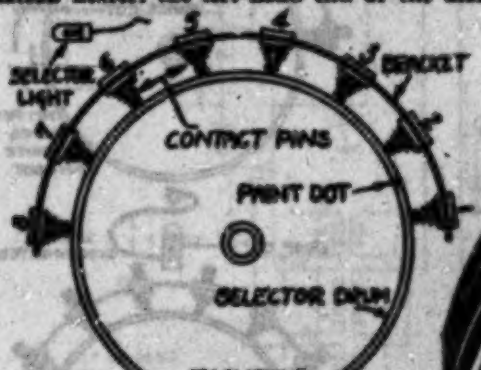


FIGURE I

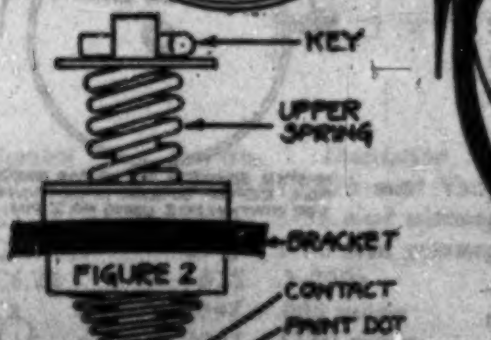


FIGURE 2

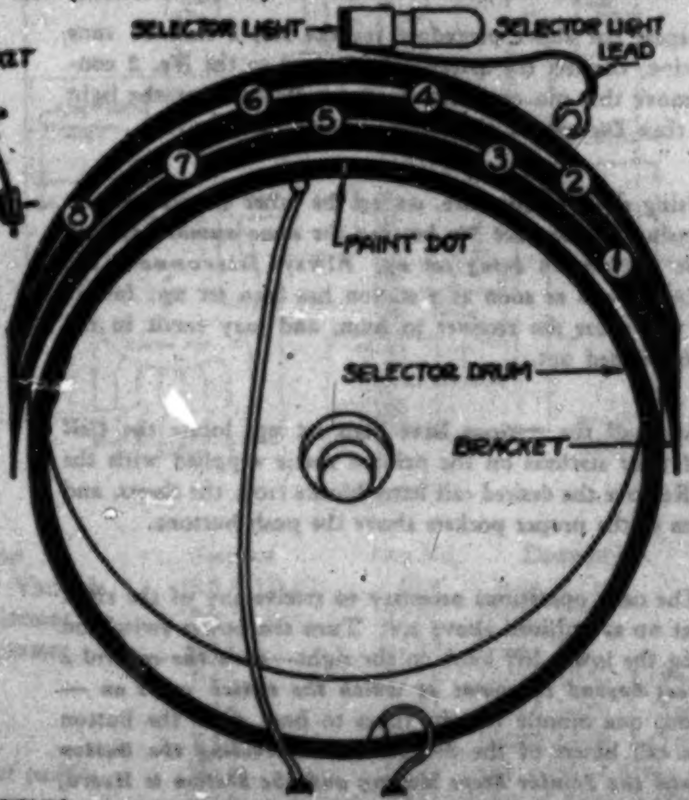


FIGURE 3

stations similarly going from left to right across the dial. For example, assume that your favorite stations operate on frequencies of 1500 kc, 1400 kc, 1300 kc, 1200 kc, 1000 kc, 900 kc, 700 kc, and 600 kc. Then the 1500 kc station would be *No. 1*, the 1400 kc station would be *No. 2*, and so on down the list with the 600 kc station being designated *No. 8*. Reference to the push buttons is not necessary since they are not used until *After* the *Master Selector* has been set up.

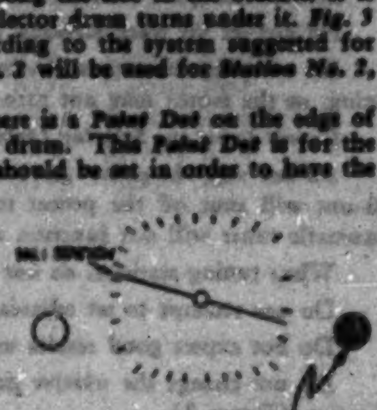
On the back of the receiver will be found the *Selector Drum* and the eight *Contact Pins* which determine the points at which the tuner will stop when the buttons are pressed. Referring to the diagrams, *Fig. 1* shows the general layout and relation of the drum and contacts. *Fig. 2* shows one of the contact pins in detail: note that while the position of the contact may be varied at will by sliding it along the slot in the bracket, it is held securely by a strong spring which will not allow it to move when the selector drum turns under it. *Fig. 3* shows the arrangement of the *Contact Pins*, each pin being numbered according to the system suggested for numbering the stations, thus *pin No. 1* will be used for *Station No. 1*, *pin No. 2* will be used for *Station No. 2*, and so on down the list.

On the *Selector Drum* are two pairs of *Contact Ribbons*. Note that there is a *Paint Dot* on the edge of the drum directly opposite the break in the ribbons on the upper half of the drum. This *Paint Dot* is for the purpose of locating the approximate position at which a given *Contact Pin* should be set in order to have the *Drum* stop for a particular station.

It is very important that the following steps be followed exactly as outlined; any deviation may necessitate re-setting some of the stations:

1. Set the receiver for reception of *Standard Broadcast Stations* as outlined previously under *"Operation."* Turn the receiver *"On,"* let it run for *at Least Ten Minutes* to allow the tubes to reach their final operating temperature.

2. Using the *Manual Station Selector* (upper right) knob, tune in the No. 1 station, that is, the one nearest the 1600 kc end of the dial. Watch the tuning eye closely, making certain that the station is tuned in perfectly.



3. Face the rear of the chassis. Attach the lead from the *Selector Light* to the *No. 1 Contact Pin;* unless the pin happens to be set exactly, the lamp will glow when the lead is touched to the pin.

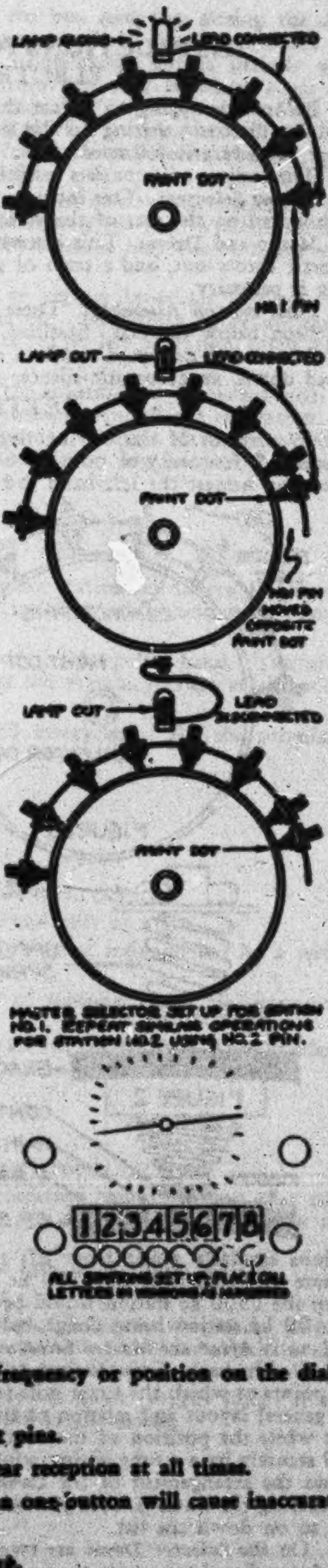
4. Observe the position of the *Paint Dot* on the edge of the *Drum.* Grasp the No. 1 pin firmly and slide it toward the *Paint Dot,* being careful not to break the connection between the *Selector Light* lead and the pin. When the pin is directly opposite the *Paint Dot,* the light will go out, indicating that the contact is properly set. To insure greatest accuracy in making this setting, slide the pin back and forth across the break between the ribbons, leaving it set half way between the points where the lamp lights. ***Be very careful not to move the Selector Drum while the pin is being set.*** When the pin is definitely in its proper position, ***Disconnect the Selector Light Lead from the Pin.***

5. Repeat the above procedure for the *No. 2* station; tune in the station, connect the *Selector Light* lead to the *No. 2* contact pin, move this pin opposite the *Paint Dot* so that the light goes out, then ***Disconnect the Selector Light Lead.***

6. Using similar procedure, set up the other six stations, in each case using the *Contact Pin* bearing the ***same number as that assigned to the station being set up.*** Always ***Disconnect the Selector Light Lead*** as soon as a station has been set up; failure to do so will cause the receiver to hum, and may result in the lamp being burned out.

7. After all the stations have been set up, locate the *Call Letters* of your stations on the printed sheets supplied with the receiver. Remove the desired call letter blocks from the sheets, and insert them in the proper pockets above the push buttons.

8. The only operations necessary to receive any of the eight stations set up as outlined above are: Turn the power switch on by rotating the lower left knob to the right—***turn the control a few degrees beyond the point at which the switch snaps on*** — allow about one minute for the tubes to heat, press the button under the call letters of the desired station ***Holding the Button Down Until the Pointer Stops Moving and the Station is Heard,*** then adjust the tone and volume. Be sure that the *Band Selector* switch is in the proper position for reception of ***Standard Broadcast Stations.***



OPERATING SUGGESTIONS

Be sure that your stations are listed in the proper order according to frequency or position on the dial. Do not confuse frequency (kilocycles) with wave length (meters).

Be sure that your stations are tuned in exactly before setting the contact pins.

Do not set up weak stations, or distant stations too weak to afford clear reception at all times.

Do not press more than one button at a time. Holding down more than one button will cause inaccurate tuning, or the motor may not turn at all.

Do not leave the Selector Light Lead connected after the pins are set up.

Do not run the motor for excessively long periods of time. While no damage will result, a protective cut-out will shut off the power to the motor after four to five minutes of ***continuous*** operation, and the automatic tuner will not function again until the motor has been allowed to cool for several minutes.

When tuning stations, ***do not release the button until the pointer stops moving.***

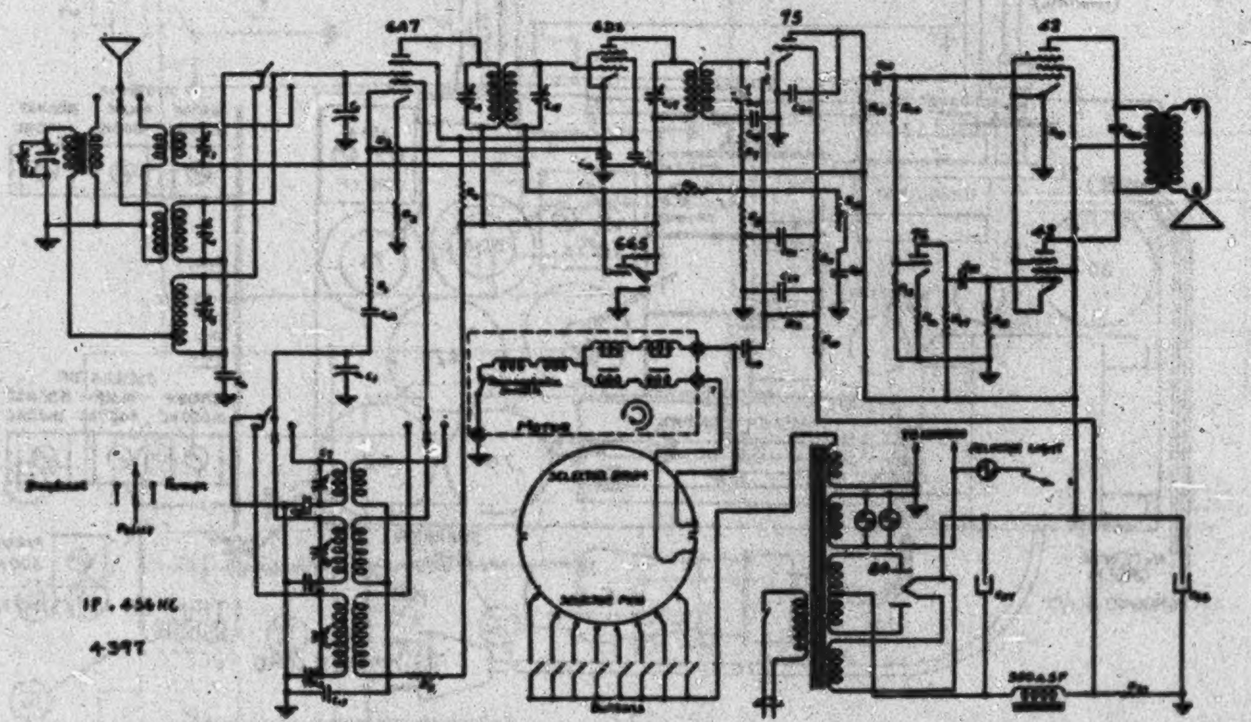
Do not attempt to set adjacent pins in the same slot too close together.

Do not expect good results unless a good outdoor antenna is used.

Do not change the relative positions of the contact pins; keep them in the same order as shown on the diagram (Figure 3).

CIRCUIT DIAGRAM *and* PARTS LIST

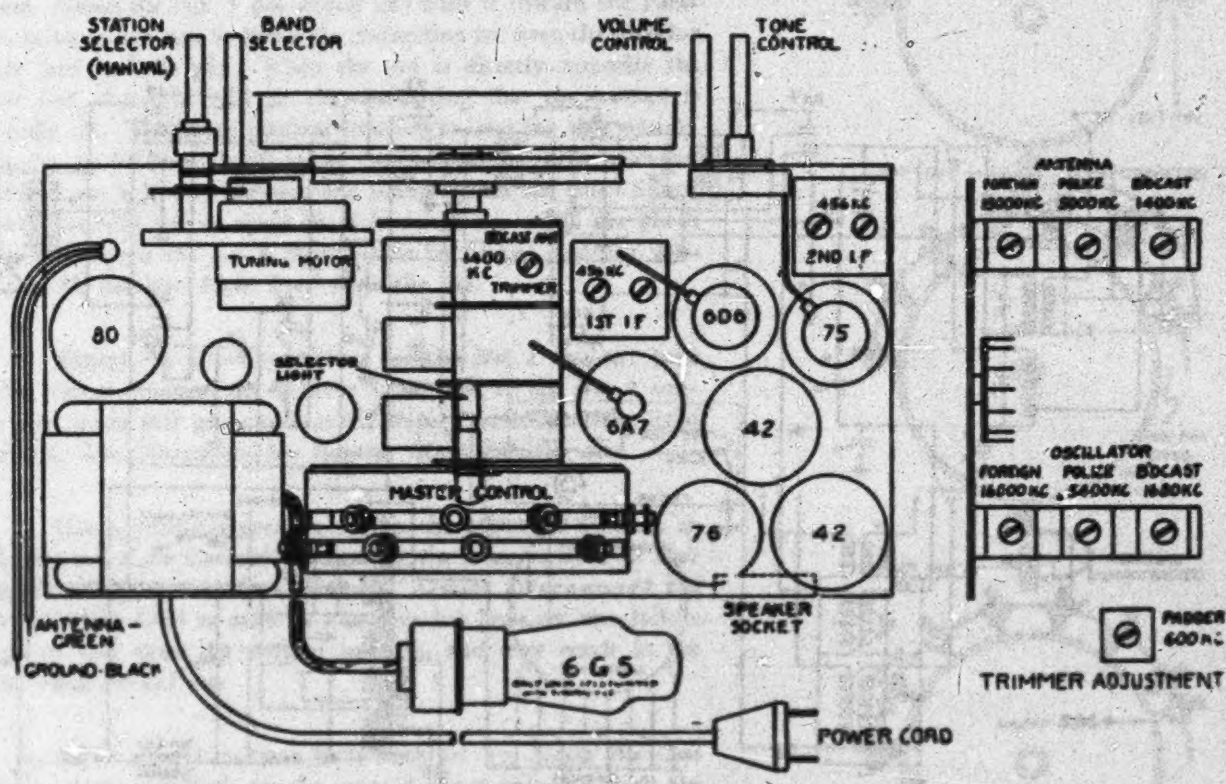
Warning! **This information to be used by a Competent Service Man only and not by an untrained person.**



Symbol	*Part No.*	*Description*	*Symbol*	*Part No.*	*Description*
C1	4354	12-375 mmf Variable	R6,9,10,11	624	1 meg. 1/3w
C3,11	1611	3-35 mmf trimmer	R8	2726	500M VC
C4,5,7,9	2597	1-10 mmf trimmer	R12	2737	2 meg TC
C6,22	572	.1-200v	R13	2730	200M 10% 1/3w
C8	2793	.006 padder	R14	2881	400M 10% 1/3w
C10	2741	1330 padder	R15	2880	100M 10% 1/3w
C12	2560	200-400 mmf padder	R16	2883	5M 10% 1/3w
C13	575	.1-400v	R18	2731	500 M 10% 1/3w
C14	2780	50 mmf mica	R19	3353	250 ohm ½ W.
C15,17		IF trimmers	R20	2882	15 ohm 10% 1/3w
C16	2792	.2-200v		4387	Power transformer
C18,20	1286	250 mmf mica		3462-1	1st IF transformer
C19	580	.05-200v		3464-1	2nd IF transformer
C21	565	.01-200v		2724	Band Switch
C23,25	576	.02-400v		2771	Antenna Coil
C24	581	.005-600v		2772	Oscillator Coil
C26	824	.002-600v		2845	B. C. Antenna Coil
C27	3375	16 mf 450v		4392	Contact Ribbon
C28	3351	8 mf 225 V. reg.		4377	Contact Pins
C29	3358	.2-400v		4394	Motor Assembly
R1,2	2689	100 ohm 1/3w		3346	Speaker 8"
R3,7,17	631	50M 1/3w		3710	Speaker 10"
R4	636	40M 1/3w			
R5	617	20M 1/3w			

TUBE LAYOUT *and* CONNECTION DIAGRAM

Tubes must be in proper position and connected as shown.



ALINEMENT PROCEDURE

***Warning!* This information is to be used by a *Competent Service Man only* and not by an untrained person**

Connect a high impedance AC voltmeter across the loudspeaker terminals. Volume control should be set a few degrees back of maximum volume position. Use a weak signal from the generator, strong signals tend to cause improper adjustments.

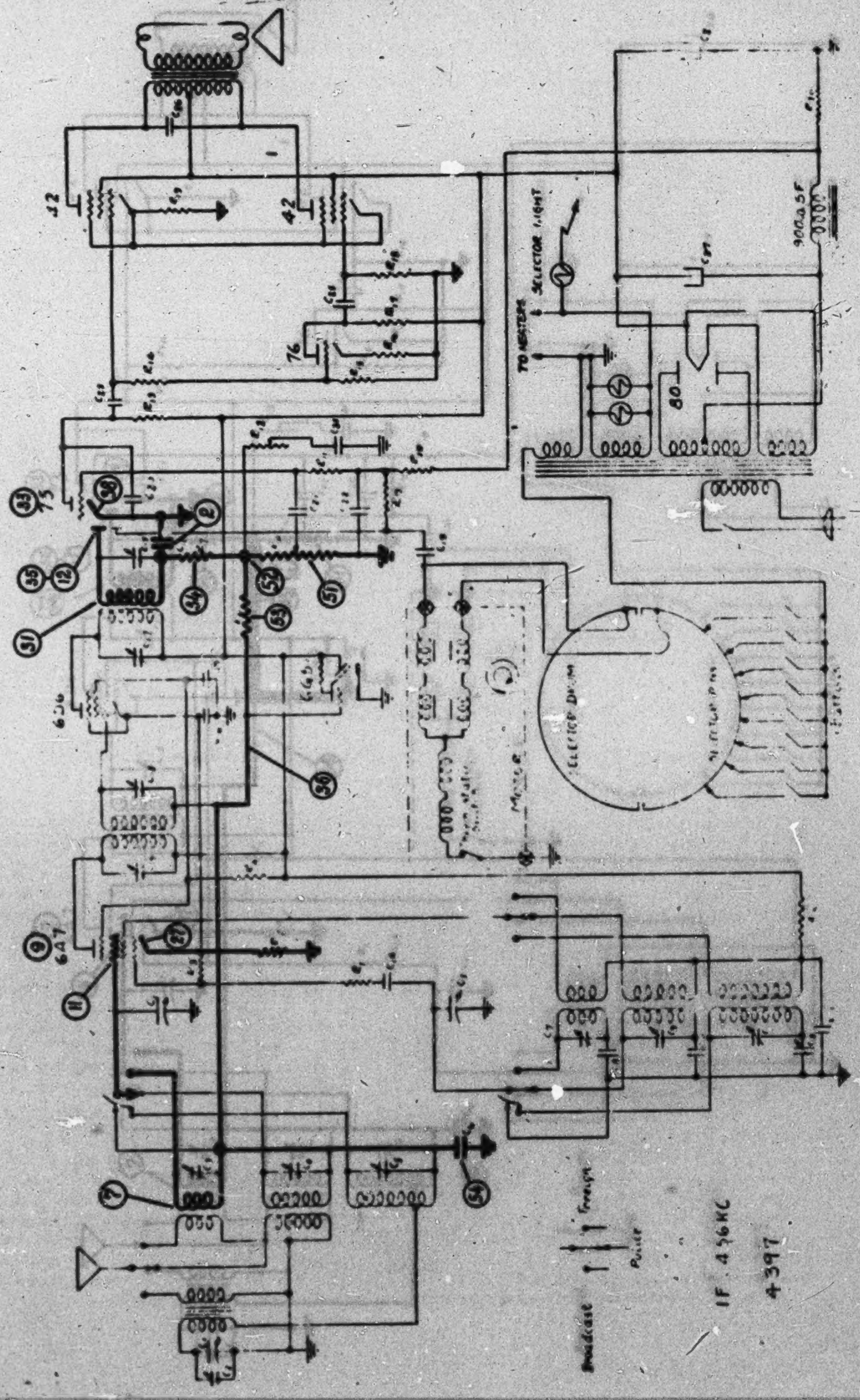
IF. Connect the generator ground to receiver chassis. Using .1 mfd. condenser in series with high side of the generator, apply 456 kc. signal to the grid of the 6D6 IF amplifier tube and aline second IF transformer trimmers. Repeat for first IF transformer, applying signal to grid of the 6A7 tube. (See above diagram for location of tubes and transformers.)

RF. (See circuit diagram for location of trimmers.) Using a 200 mmf. condenser in series with the high side of the generator, turn band selector switch all the way to the left, tuning condenser to minimum capacity, feed 1680 kc. signal to antenna terminal and adjust broadcast oscillator trimmer for top frequency. Set generator frequency at some point around 1400-1500 kc., and adjust broadcast antenna and RF trimmers. Set generator for 600 kc., tune receiver to signal and adjust the padder. The tuning condenser should be rocked back and forth through the signal while varying the padder in order to assure perfect alinement.

A 400 ohm resistor must be used in series with the generator as a "dummy" antenna for proper alinement of the two short wave bands. Set the band selector switch in the center position, adjust the oscillator top frequency for 5400 kc., then aline the antenna trimmer at about 5000 kc. With the band selector in the extreme right position, adjust the top frequency of the high frequency band to 16,000 kc., and aline the antenna trimmer at about 15,000 kc. In order to make sure that the top end of the last band is set properly, it is best to screw the oscillator trimmed down tight, then unscrew to the second peak. The antenna trimmer should be screwed down tight, then unscrewed to the first peak. This procedure must be followed in order that the oscillator and RF circuits will be set in the correct relation to each other, otherwise a "dead" spot at a lower frequency will result, and the dial calibration will not be correct. Usually, it is best to rock the tuning condenser back and forth slightly while making these adjustments at high frequencies.

PLAINTIFF'S EXHIBIT NO. 2B

Detrola Model 175



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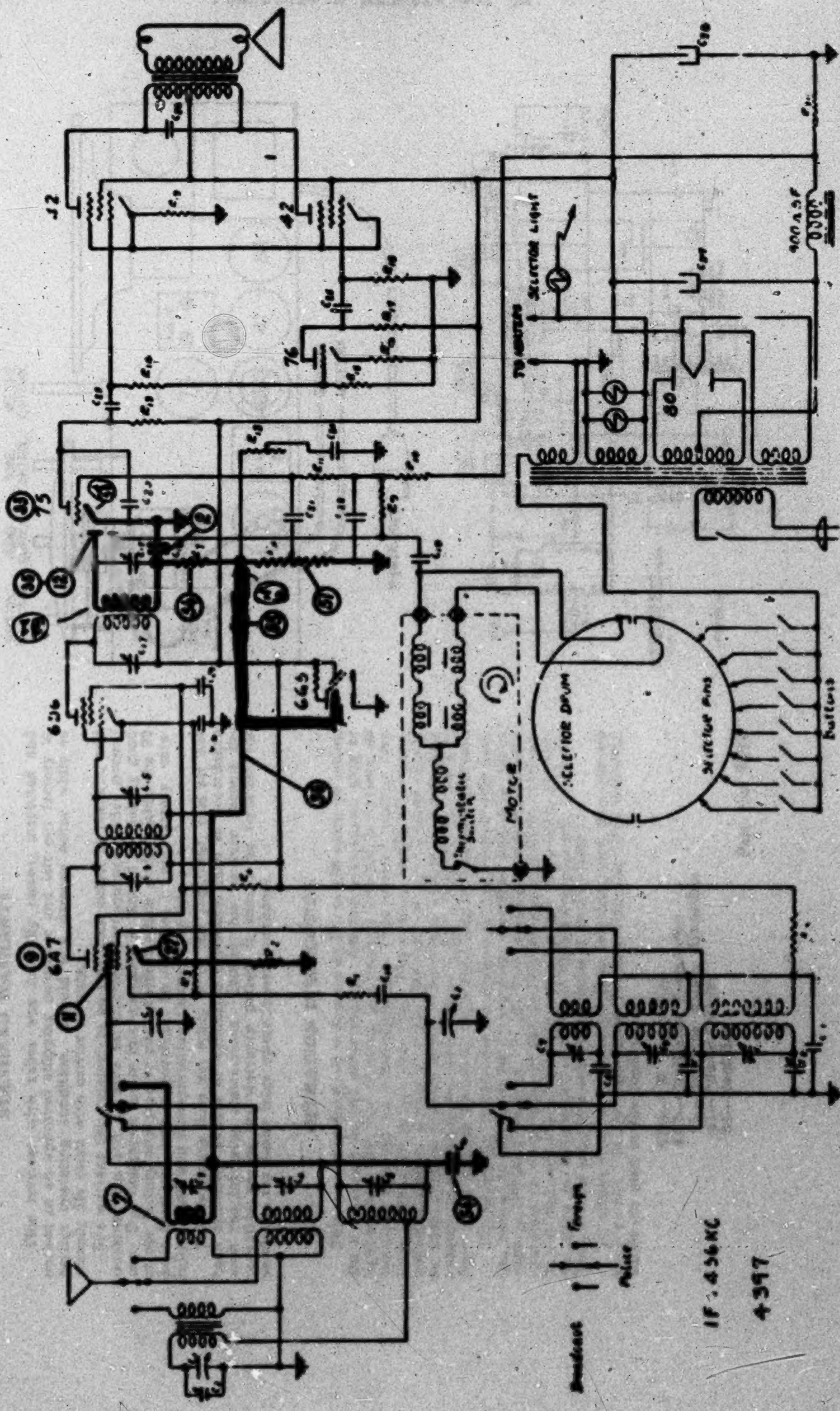
PLAINTIFF'S EXHIBIT NO. 2B-1

Detrola Model 175



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PLAINTIFF'S EXHIBIT NO. 3A

Detrola Model 178

STANDARD WARRANTY

This receiver with tubes was carefully tested, inspected and packed in an approved shipping container and left our factory in perfect operating condition. Should any damage occur while in transit, file claim with carrier at once.

We warrant this receiver to be free from defect in material and workmanship and to give satisfactory performance under normal use. Our obligation under this warranty is limited to making good at our factory any part or parts thereof which shall, within the 90 days from the date of purchase, be returned to our factory, carefully packed and transportation charges prepaid.

This warranty does not apply if, in our judgment, this set has been mis-used, abused or connected otherwise than in accordance with the following instructions. Should this receiver become inoperative within the warranty period, it should be returned for service to the dealer from whom it was purchased.

OPERATION INSTRUCTION

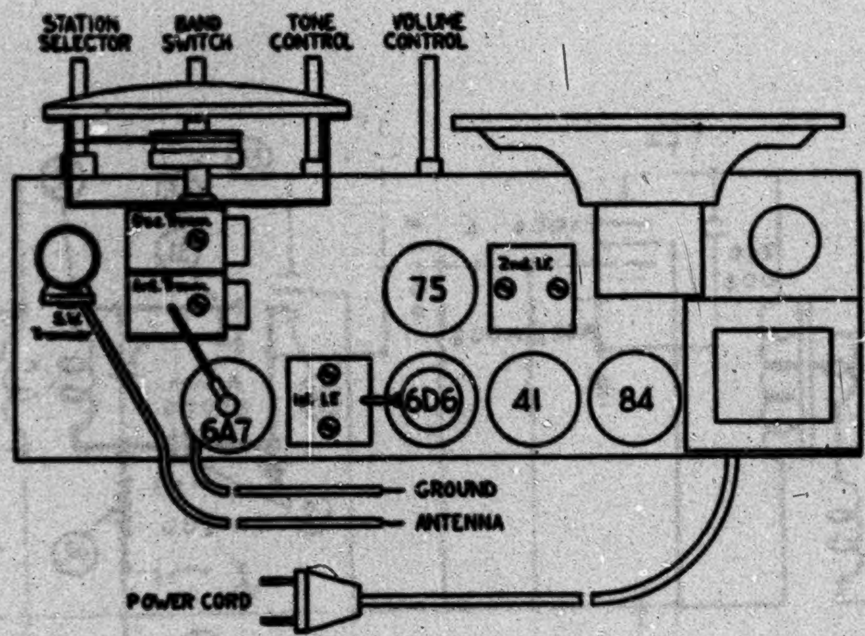
This receiver is designed to operate on 105 to 125 volts, 60 cycles. Do not connect to any other supply. Connect attachment plug to light socket. See that all tubes are properly inserted in sockets, as per chart showing top view of chassis. This receiver requires very little antenna for proper operation. The average length of antenna, including lead-in, should be about fifty feet. A good ground should be used, such as a water pipe. Turn power switch on by turning volume control knob to right. Allow a short time for the tubes to heat. Turn volume control to right until desired volume is attained.

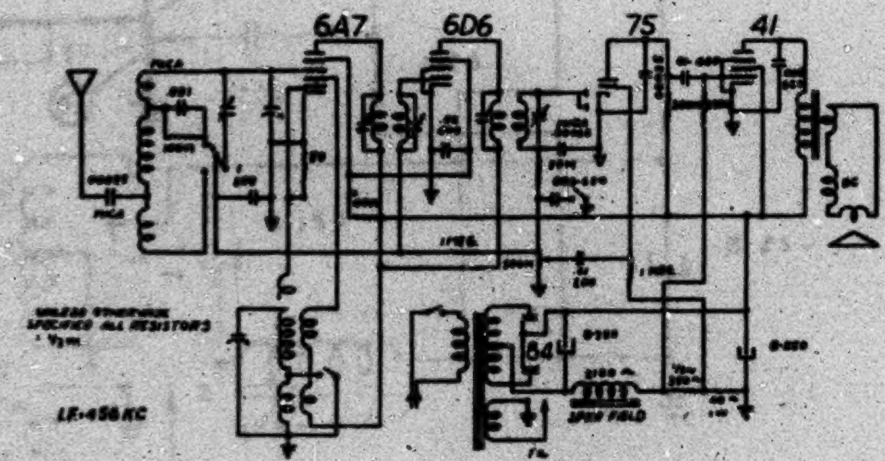
The automatic volume control feature of the receiver will keep the volume to this level for all stations. Set band switch in either right or left hand position. In left hand position broadcast stations operating on frequencies of 540 to 1720 kilocycles will be received. In the right hand position of the wave switch, short wave stations operating on frequencies of 2300 to 6500 kilocycles will be heard. Turn station selector knob until station is heard clearly.

To adjust tone of receiver for bass response, turn tone control knob to left. To the right gives brilliant response. The following tubes are used in the receiver:

6D6—I.F. Amplifier
6A7—Oscillator Translator
75—Detector Audio Amplifier
41—Power Output
84—Rectifier

Part No. 3898





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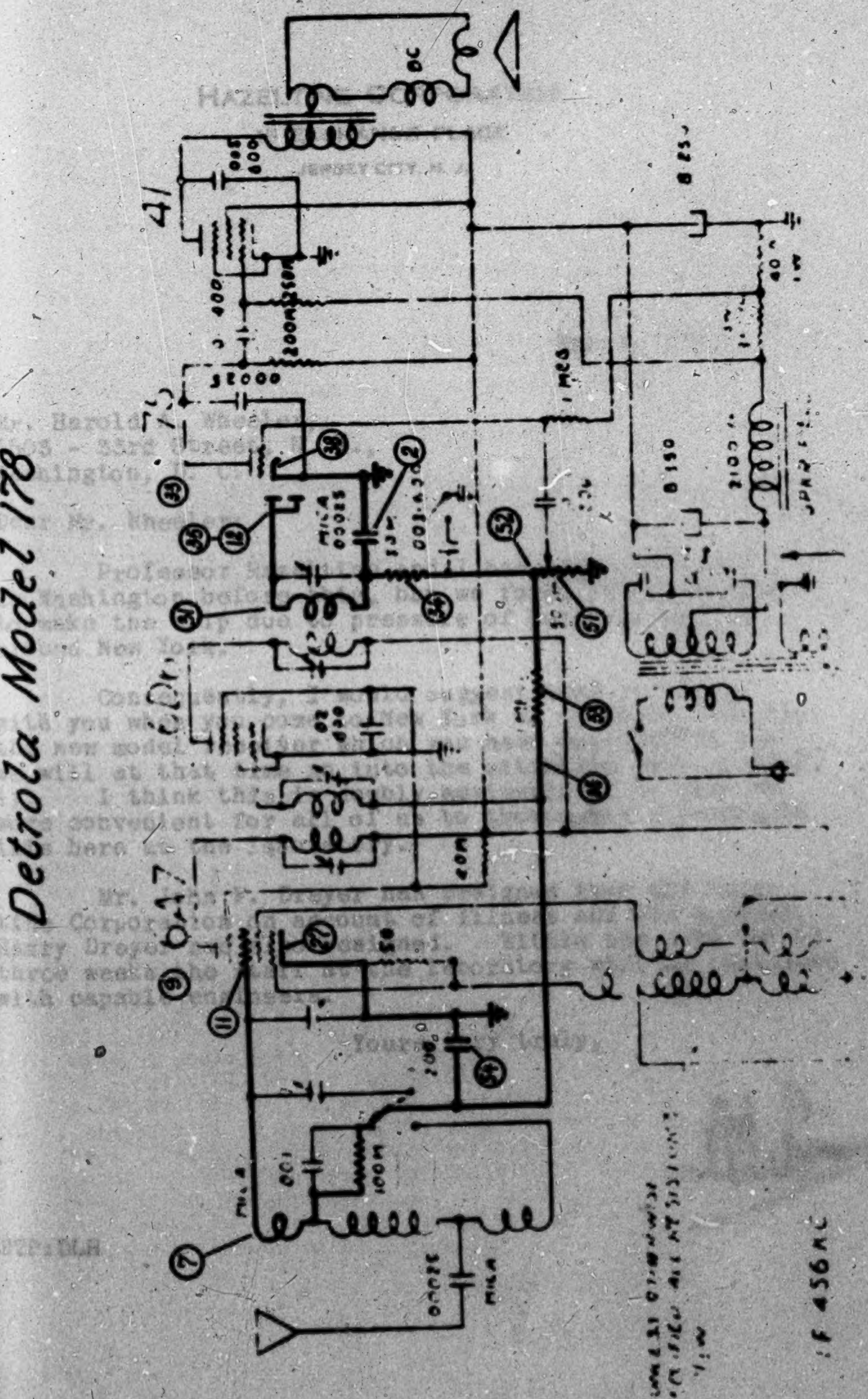
PLAINTIFF'S EXHIBIT NO. 3B



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PLAINTIFF'S EXHIBIT NO. 4

HAZELTINE CORPORATION
15 EXCHANGE PLACE
JERSEY CITY, N. J.

May 4, 1926.

Mr. Harold A. Wheeler,
5503 - 33rd Street, N. W.,
Washington, D. C.

Dear Mr. Wheeler:

Professor Hazeltine and I had expected to be in Washington before this, but we found it impossible to make the trip due to pressure of business in and around New York.

Consequently, I would suggest that you bring with you when you come to New York on or about June 7th the new model receiver which you have constructed and we will at that time go into the situation very carefully. I think this is doubly advisable as it will be more convenient for all of us to thoroughly investigate this here at the laboratory.

Mr. John F. Dreyer has resigned from the Hazeltine Corporation on account of illness and his brother, Harry Dreyer has also resigned. Within the next two or three weeks the staff at the laboratory will be increased with capable engineers.

Yours very truly,

R. T. Pierson

President.

RTP:DLH

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PLAINTIFF'S EXHIBIT NO. 5

5503 Thirty-third Street, N.W.
Washington, D.C.
May 17, 1926.

Mr. R. T. Pierson, President
Hazeltine Corporation
Jersey City, N. J.

Dear Mr. Pierson:

The delay in answering your letter of May 4 is the result of an emergency which made it necessary for me to go on a short trip to Omaha. On my return from there, I had a few hours between trains in Chicago, so I took the opportunity to visit the Howard factory. I am very favorably impressed with the type of engineering which appears in their sets.

In the course of my conversation with Mr. Howard and his chief engineer, Mr. Hanson, I described to them some of the advantageous features of the Audiostat and of the other device Mr. Dreyer reported on for tuning a two-dial set with but one knob. They were very enthusiastic about both, especially the Audiostat, but I did not, of course, disclose to them any details of my circuit for accomplishing the performance of the Audiostat.

I am sorry to hear of the resignation of Mr. Dreyer and his brother, for I considered them both very competent. When the new engineers are appointed, I shall be glad to cooperate with them in every way. I am now in a position to state definitely that I shall be wholly at the disposal of the Hazeltine Corporation from June 14 to August 14, inclusive. Both dates are one week later than I at first planned.

Unfortunately, examinations this week and later on prevented me from attending the Grebe suits this week, as I had hoped to do. This is a disappointment to me.

Relative to the set I have assembled which embodies the Audiostat, I am sorry to say that it is in a very "temporary" form, as you can imagine from the fact that I assembled the set and carried on all the experimental work during about ten days of the Christmas vacation. For this reason, I could not move it from my laboratory. I suggest that I build the design into a three or four stage shielded Neutrodyne receiver already constructed, or still better in the process of construction at the Stromberg-Carlson or Howard factories, since the latter procedure would obviate some of the reconstruction difficulties. The device which accomplishes the control is not at all complicated, but must be connected to most of the stages in one way or another.. What is your advice on this question?

Very truly yours,

Harold A. Wheeler

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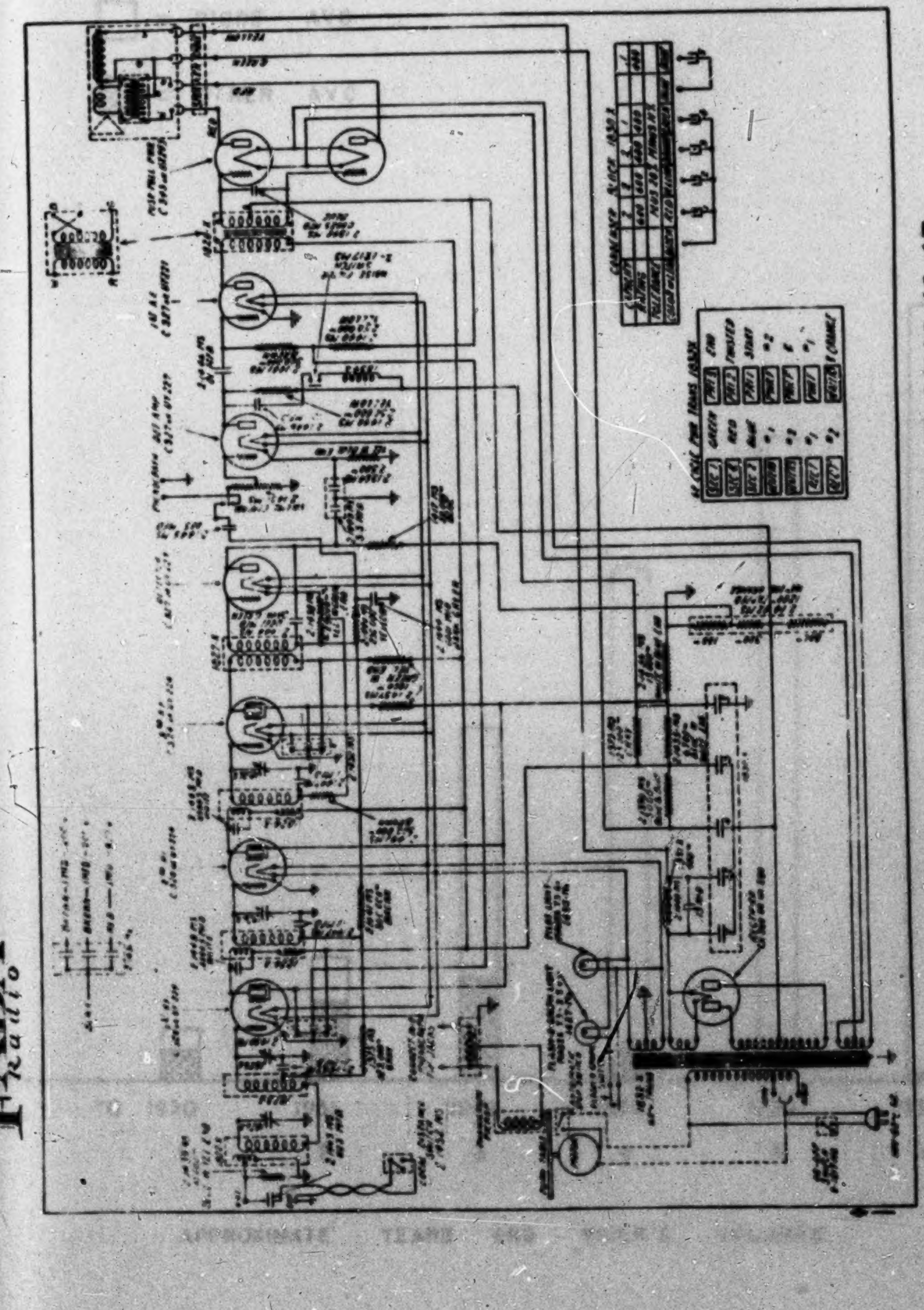

Wiring Diagram for Fada Models 42-44-46-41-47
(Phonograph Circuit Applies only to model 47)

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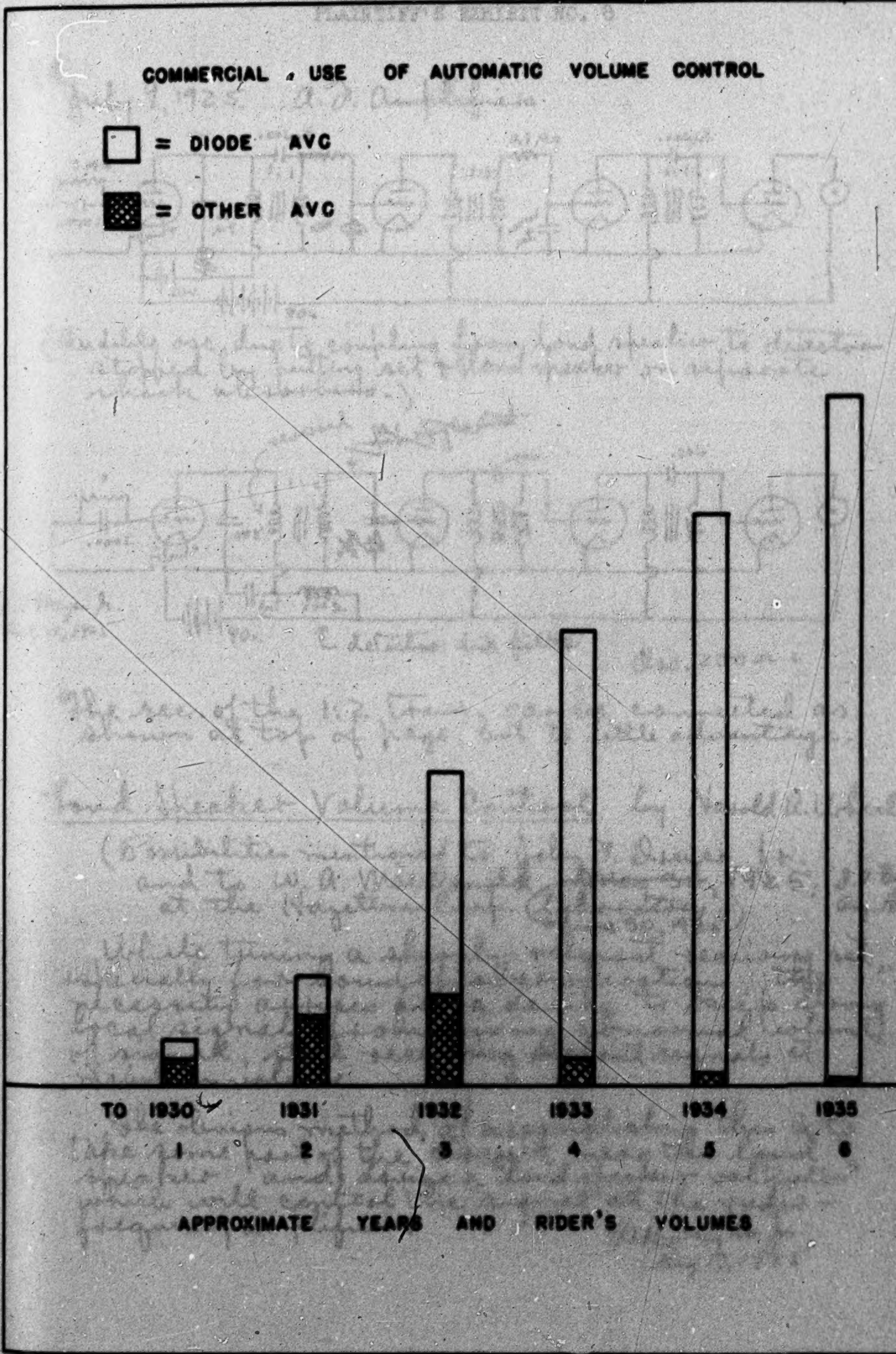
PLAINTIFF'S EXHIBIT NO. 7



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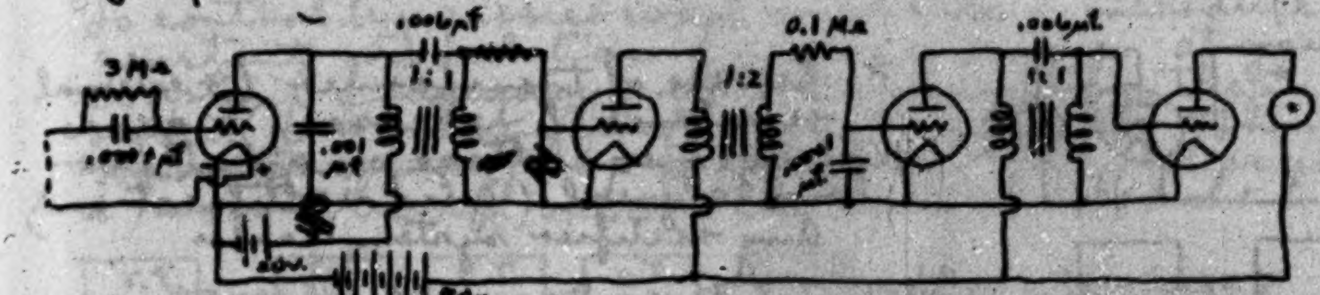
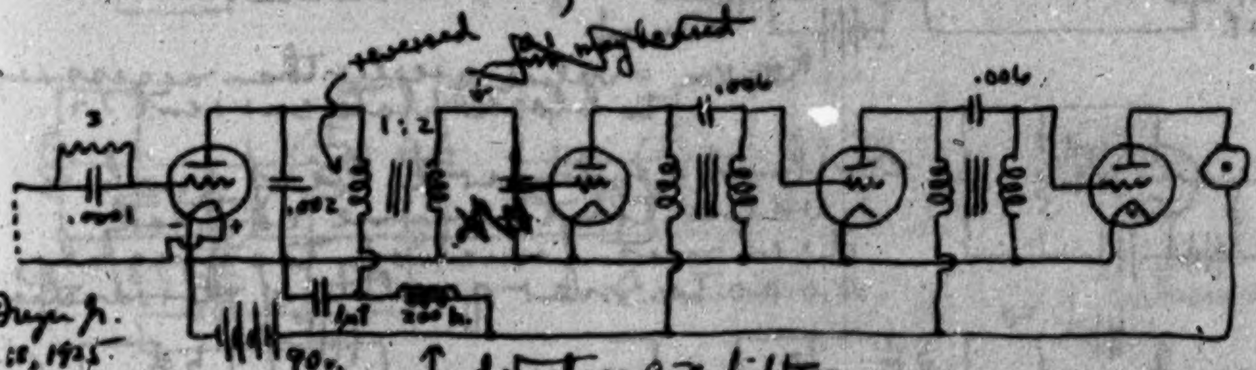
PLAINTIFF'S EXHIBIT NO. 8

14 July 9, 1925. A.F. Amplifiers



(Audible osc. due to coupling from loud speaker to detector stopped by putting set & loud speaker on separate shock absorbers.)



J.F. Dreyer Jr.
Aug. 18, 1925

↑ detector A.F. filter

Osc. 200 ~

The sec. of the 1:2 trans. can be connected as shown at top of page, but to little advantage.

Loud Speaker Volume Control by Harold A. Wheeler

(Possibilities mentioned to John F. Dreyer, Jr. and to W. A. MacDonald ~~June 30~~, 1925, at the Hazeltine Corp. (Laboratory.) → June 30, 1925 J.F. Dreyer Aug. 18, 1925

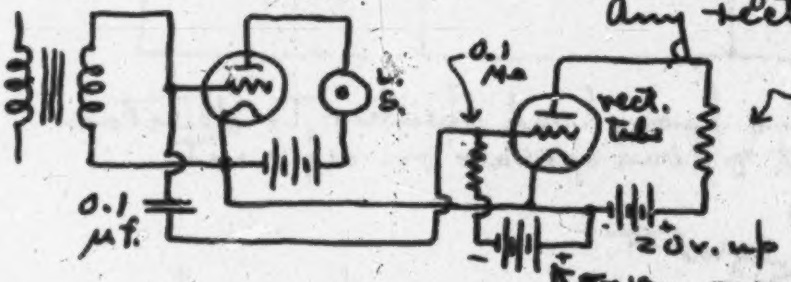
While tuning a sharply-resonant receiving set, especially for loud speaker operation, the necessity arises for a device to keep strong local signals from giving abnormal volume of signal, still receiving distant signals at maximum volume.

The obvious method of accomplishing this is to take some part of the circuit near the loud speaker and devise a "loud speaker voltmeter" which will control the signal at the radio-frequency amplifier.

W. H. Taylor Jr.
Aug 17, 1925

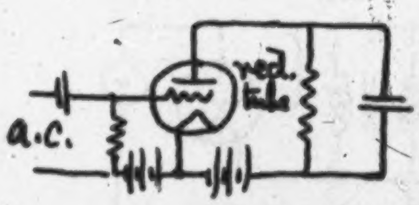
July 9, 1925. Auto-Volume-Control (con.)

* Sec. res. of transformer (+ external resistance if necessary) gives average neg. voltage on grid for loud signal (grid rectification)
Any rectifier system is apple

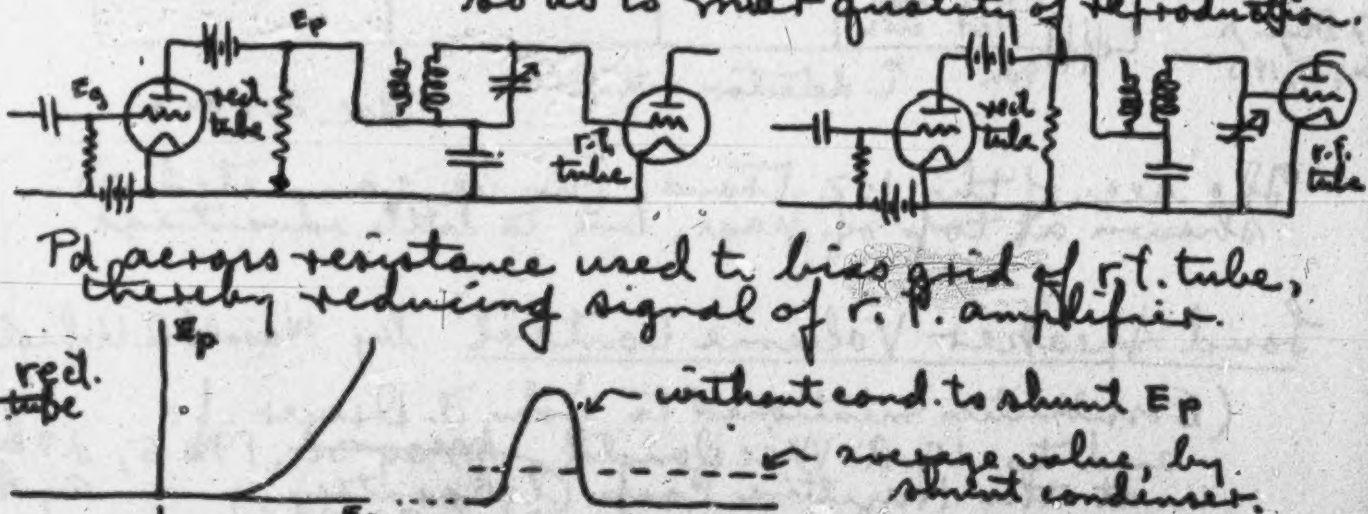


← Signal above certain value, plate current gives Pd across this resistance

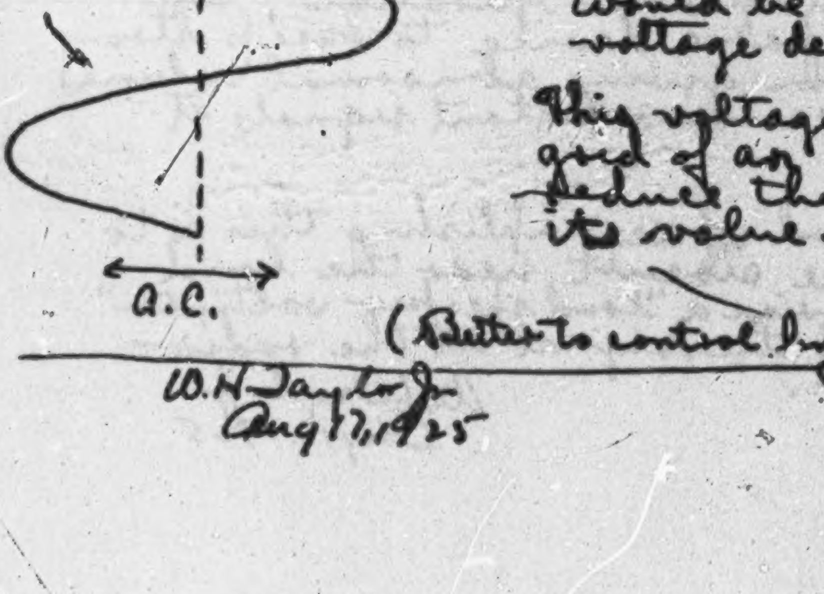
10v. = value greater than necessary to block plate current



← Shunt condenser to be of such value that volume control does not function too quickly, so as to mar quality of reproduction.



Pd across resistance used to bias grid of r.f. tube, thereby reducing signal of r.f. amplifier.



← without cond. to shunt Ep

← average value, by shunt condenser.

In above curve the effect (----) would be negligible if a.c. voltage decreases less than 50%.

This voltage should bias the grid of an r.f. tube so as to reduce the signal, or limit its volume.

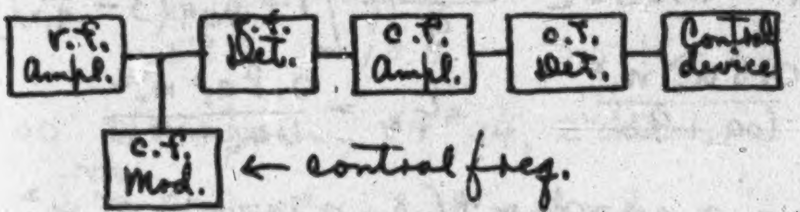
(Better to control by r.f. carrier wave.)

W. H. Taylor Jr.
Aug 17, 1925

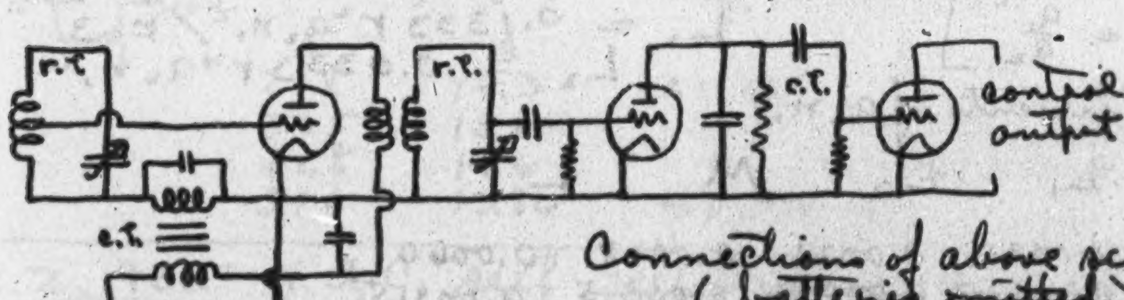
J. F. [illegible]
Aug. 18, 1925

July 11, 1925 Auto-Volume-Control (con.)

To control by carrier wave amplitude - introduce constant modulation of carrier wave at given constant frequency, detect and amplify, then use output for radio freq. signal control. ~~variation of freq~~ This "control freq." should occupy a narrow band outside the useful a.f. and r.f. bands.



← see July 9, 1925



Connections of above scheme (batteries omitted)

Adapted to representative receiving set.

Conventions: ◯ = tube

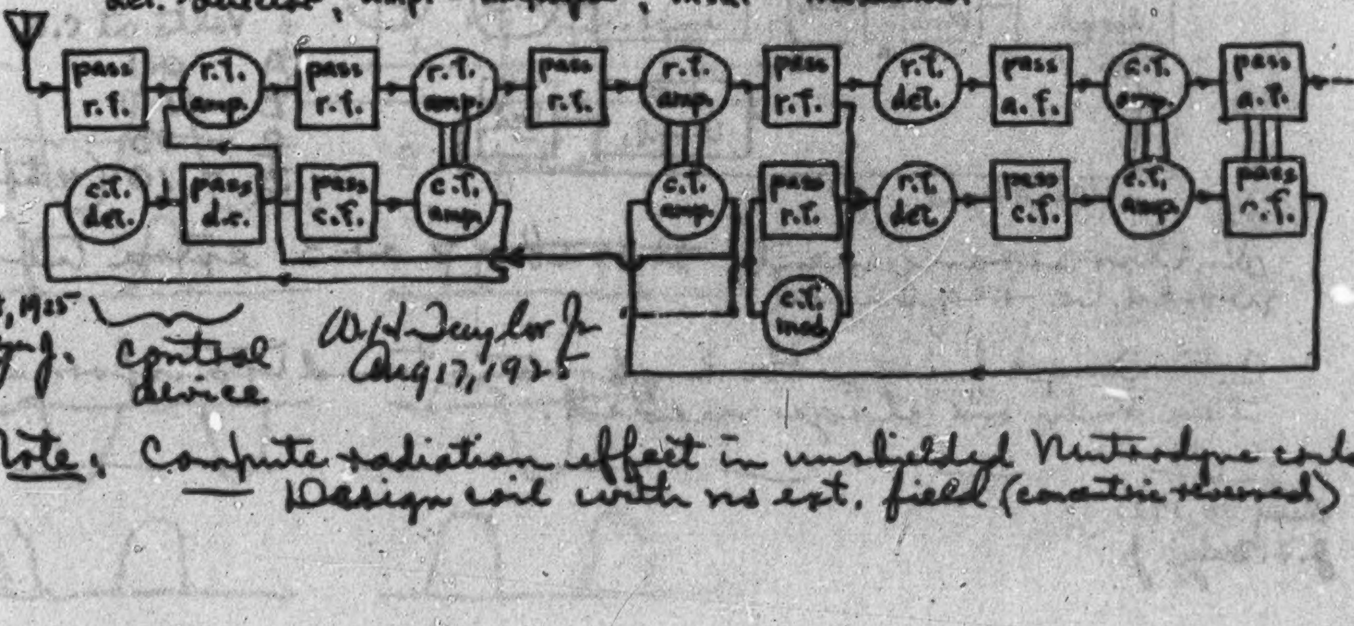
= tube reflexed if desired

r.f. = radio freq. (signal)
a.f. = audio freq.
c.f. = control freq.

combined filters if desired

□ = filter (or resonant) circuit

det. = detector, amp. = amplifier, mod. = modulator



Aug. 18, 1925 J. F. Dreyer Jr.

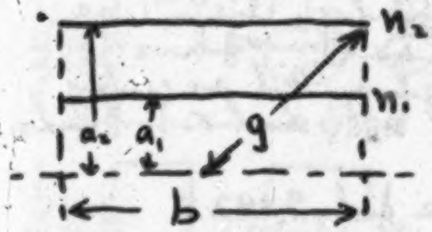
Control device

W. A. Taylor Jr. Aug 17, 1925

Note. Compute radiation effect in unshielded Neutrodyne coils — Design coil with no ext. field (concentric reversed)

32

July 20, 1925 "Neutroid" – "Neutroidal Coil":
(coaxial, concentric helices)



$$L = L_1 + L_2 - 2M$$

$$M = 0.0502\,\frac{n_1 n_2 a_2^2}{g}\left[1 + \frac{a_1^2 a_2^2}{8g^4}\left(3 - \frac{b^2}{a_1^2}\right)\right]$$

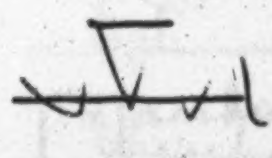
$n_1 a_1^2 = n_2 a_2^2$ $\quad L_1 = \dfrac{0.8\,a_1^2 n_1^2}{6a_1 + 9b}$ $\quad L_2 = \dfrac{0.8\,a_2^2 n_2^2}{6a_2 + 9b}$

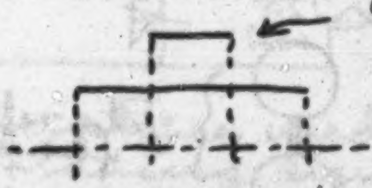
Let $\left.\begin{array}{l} b = 2a_2 \\ r = \frac{a_1}{a_2} \end{array}\right]$

$$M = 0.0439\, r^4 (1 + 0.107 r^2)\, a_2 n_1^2$$
$$L_1 = 0.1333\, r^2 a_2 n_1^2 / r+3$$
$$L_2 = 0.0333\, r^4 a_2 n_1^2$$

Coefficients of $a_2 n_1^2$:

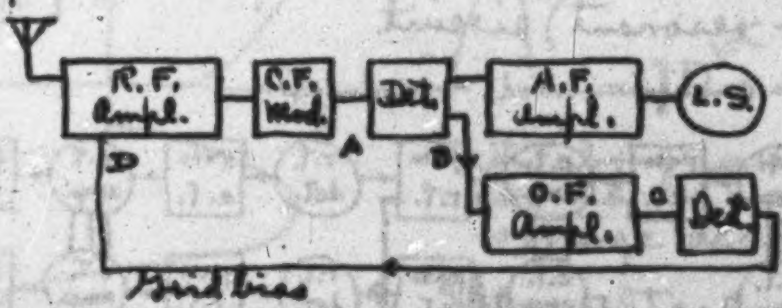
r	L_1	L_2	M	L
0.5	0.0095	0.0021	0.0028	0.0060
0.3	~~0.00027~~ 0.0036	~~0.00036~~ 0.00027	~~0.00315~~ 0.00036	0.00315





Outside coil ~~Primary~~ shorter gives higher inductance, but more exposure of inner coil

July 20, 1925 "Autovol" volume control (con.)



C.F. about 100 kc.

Volts at C.F.
A – 0.1
B – 1.0
C – 50
D – 10 (rectified)

In this arrangement, ~~[struck]~~ 2 or 3 extra tubes would be required

C.F. Amplifier with high-ratio tuned transformer, then only one stage needed.

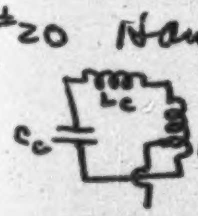
Aug. 18, 1925
J.F. Dreyer Jr.

Dec. 1, 1925 Dreyer experimental data.

S-C 1b, 52 #22, 5×2 prim., 3" sec.

λ	A		
218	16.1	8.0 K~	½ voltage both sides
335	14.1		
428	11.8		
510	10.0	3.5 K~	

#20 New prim., 84 #24, 2" diam.



}45 #24 only, 2½", gnd. end

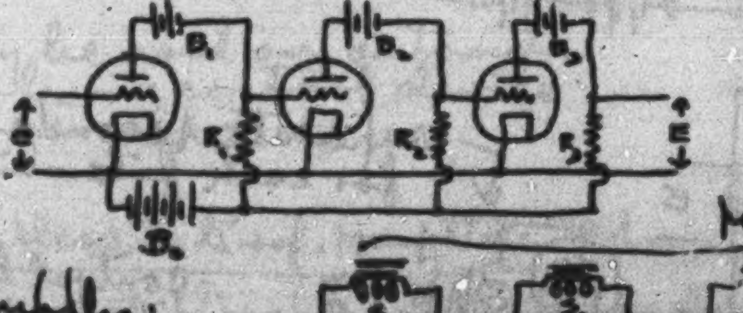
L_c = 3.0 mh. (λ_0 = 186)
C_c = 162 μμf.

λ	A	
218	14.3	21. K~
335	15.45	
428	14.6	
510	13.86	4.7 K~

196 – 643 λ
.0005 cond.

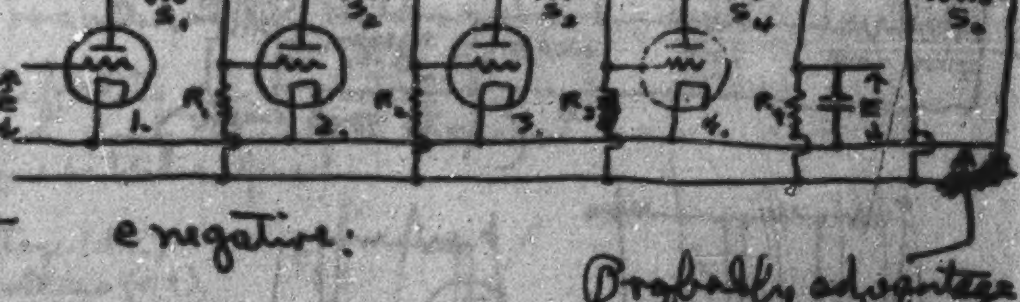
Dec. 2, 1925 { A.C. "self-rectified" plate supply for direct current (voltage) amplifier

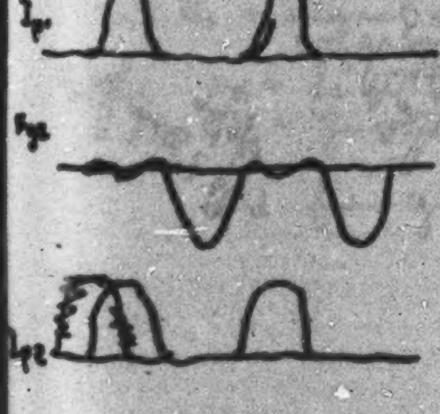
Usual d.c. amplifier:



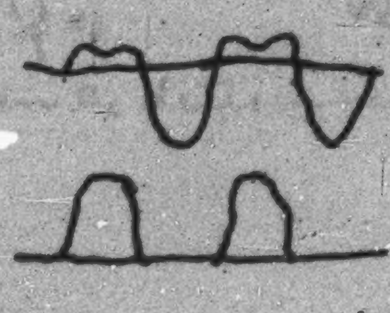
B_0 supplies R drop
B_{123} supply tubes drop

A.C. supply:





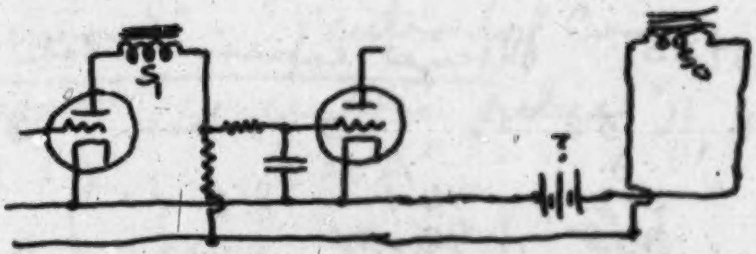
e negative:



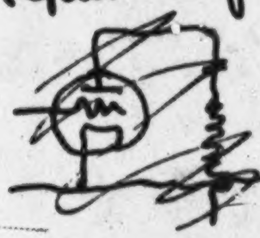
Probably advantage to have grids slightly negative and constant A.C. in series to compensate.

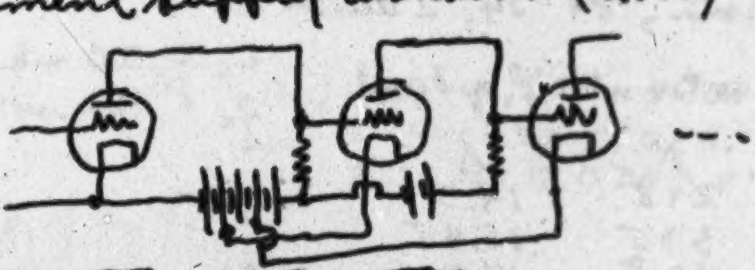
12/18/25
V.E.W.
1/6/26
[illegible]

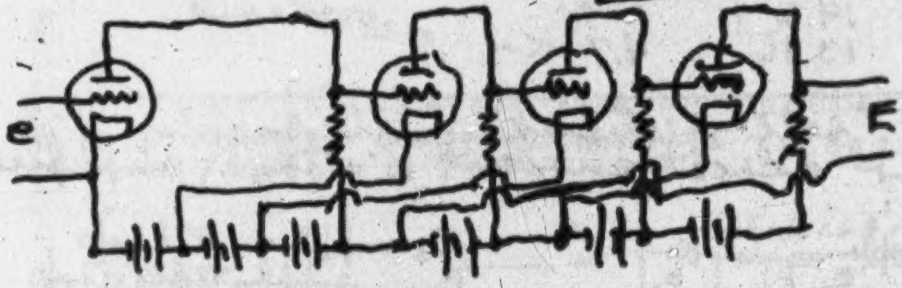
78
Dec. 2, 1925 (con.)

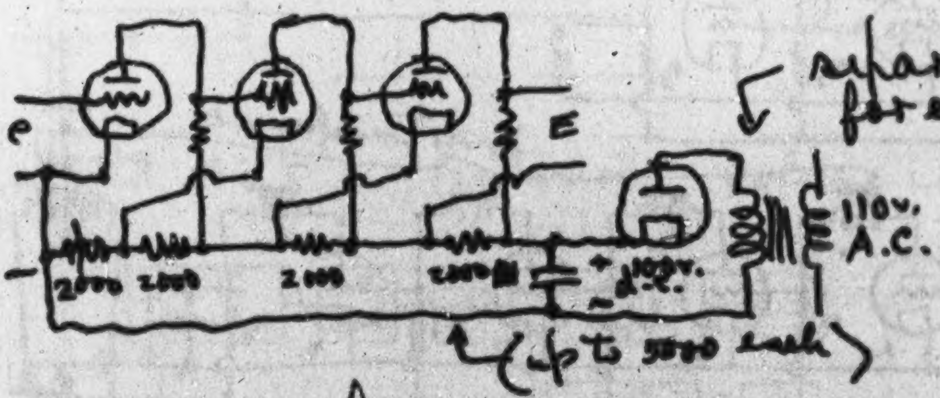


(Probably best without filtering grid voltage)
separate filament supply instead: (A.C.)



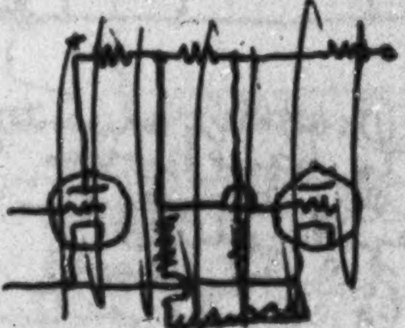






separate secondary for each filament.

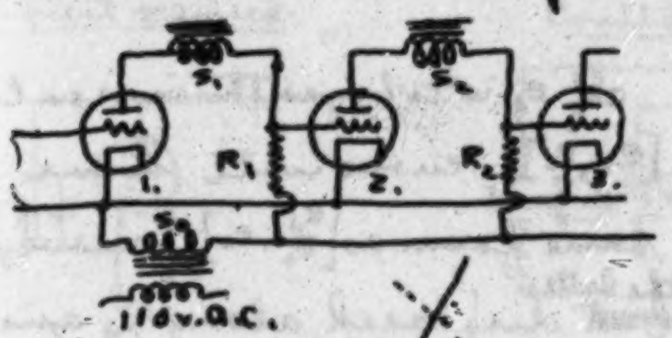
control by fil. of rect. tube

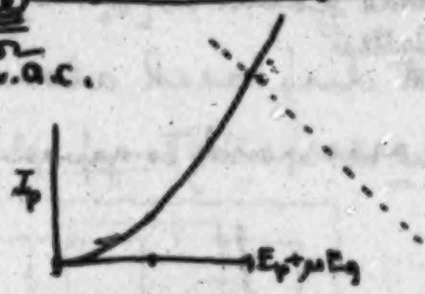


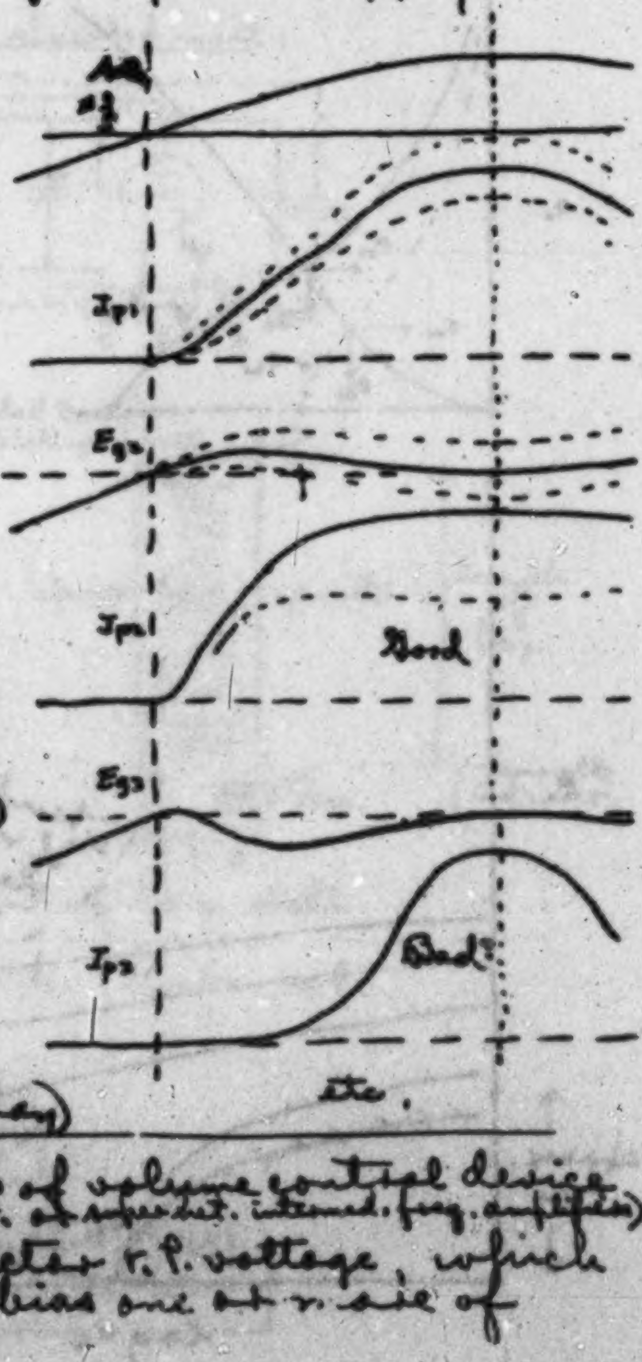
12/18/25
J.E.W.

9/6/26
J. F. Rogers Jr.

Dec. 2, 1925 (con.) Self-rectified plate supply







Dotted lines when E_{g1} varies.

The idea is obviously O.K. and can be operated (curves assume d.c. on filament)

(May be used on automatic volume control device finally.)

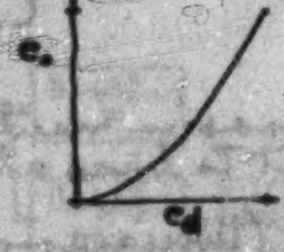
(Desc. to Prof. Hazeltine today)

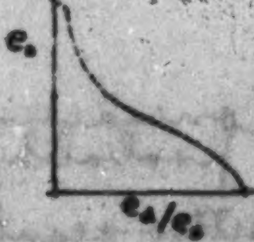
Dec. 8, 1925 Graphical analysis of volume control device (first r.f. or superhet. intermed. freq. amplifier)

carrier signal is amplified to give detector r.f. voltage, which is rectified and amplified to bias one or more of the r.f. amplifier tube grids.

Let e_0 = bias voltage (d.c.)
e_d = det. voltage (r.f.)
e_s = signal voltage (r.f.) (of carrier wave)

Then e_d = function of e_0 & e_s
e_0 = function of e_d

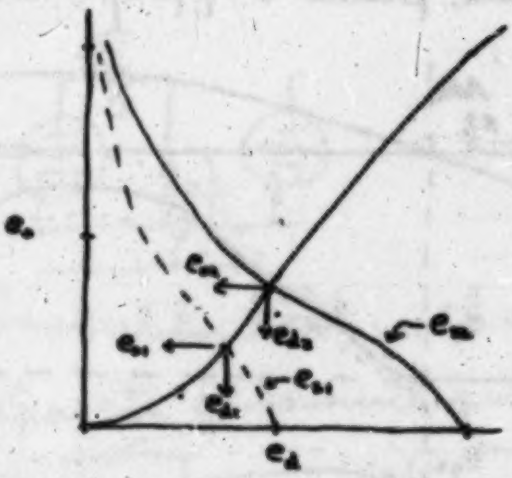




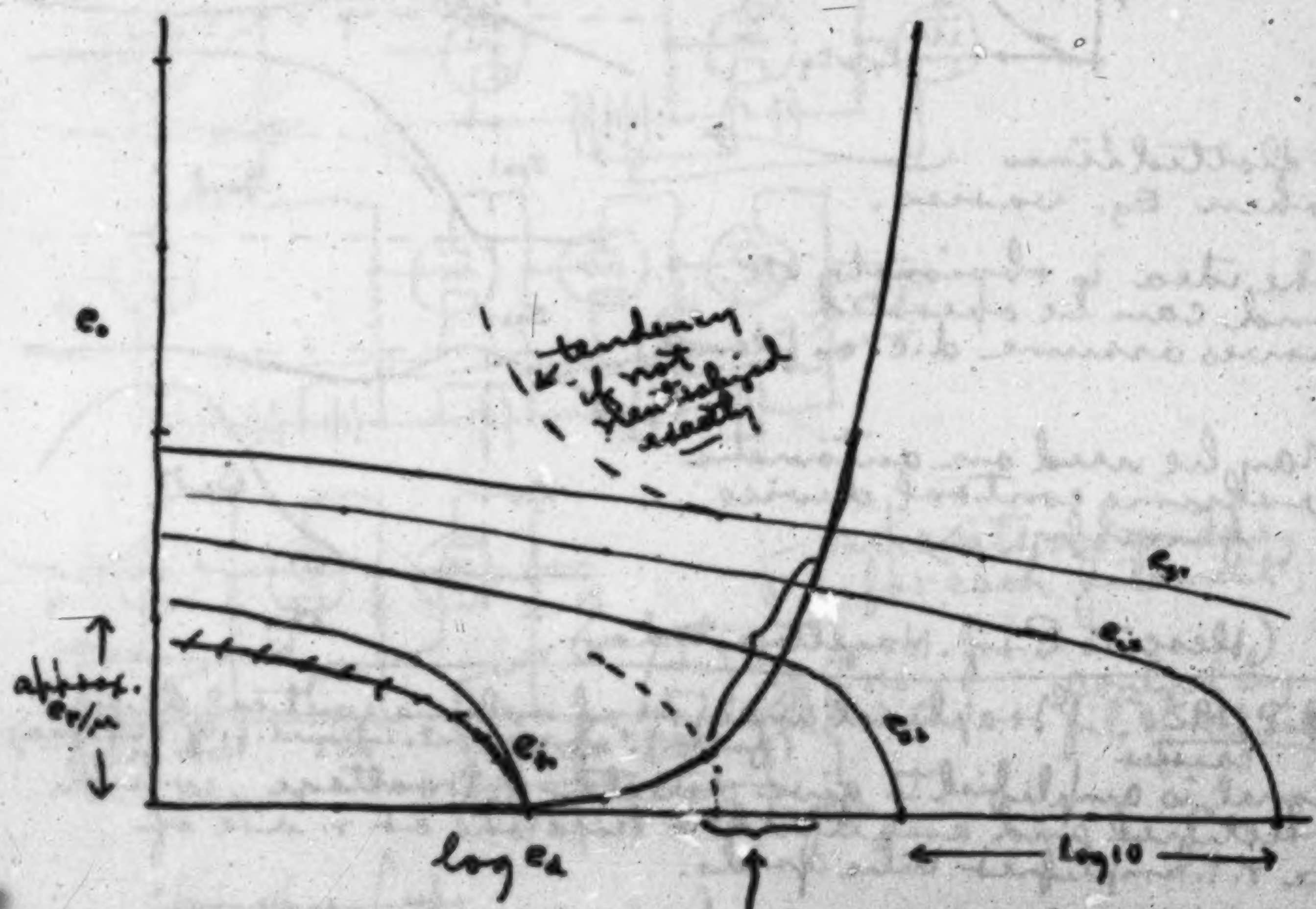
e_d for given e_s determined by intersection of curves.

4/5/26 [illegible] 12/15/25 V.E.W.

80
Dec. 8, 1925 (con.)



If e_d is to logarithmic scale, $[e_d, e_o]_{e_s}$ curve will have same form as $[\frac{e_d}{e_s}, e_o]_{e_s}$ curve, the latter displaced along e_d axis to correspond to given e_s.



e_d doubled only, while e_o multiplied by 100.

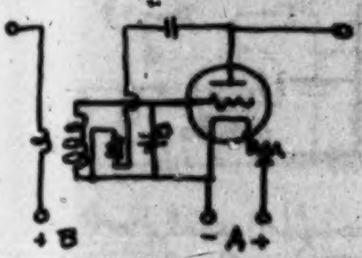
Considering error in neutralization probably best to bias all r.f. tubes & shield set.

Better regulation (twice as good, if bias depends on double rectification (4th power of e_d), as by auxiliary control of frequency.

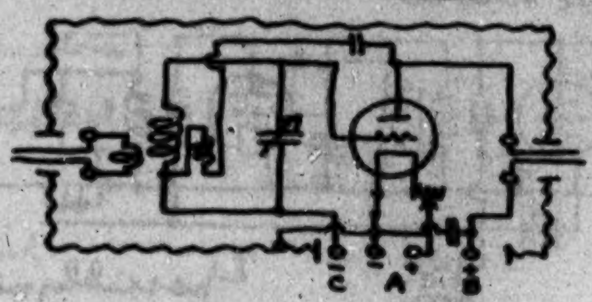
12/18/25
V.E.W.

Dec. 9, 1925 R.F. amplifier unit for experiments

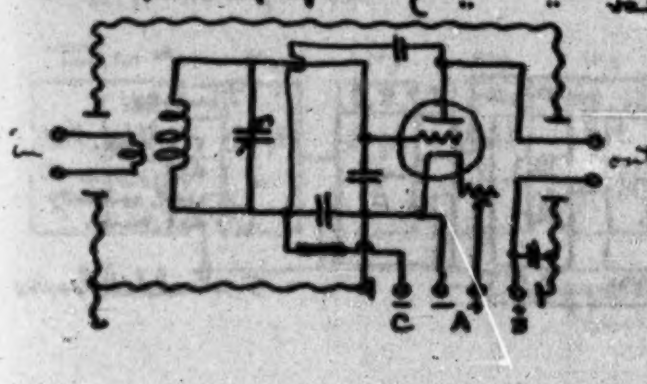
Simplest required:

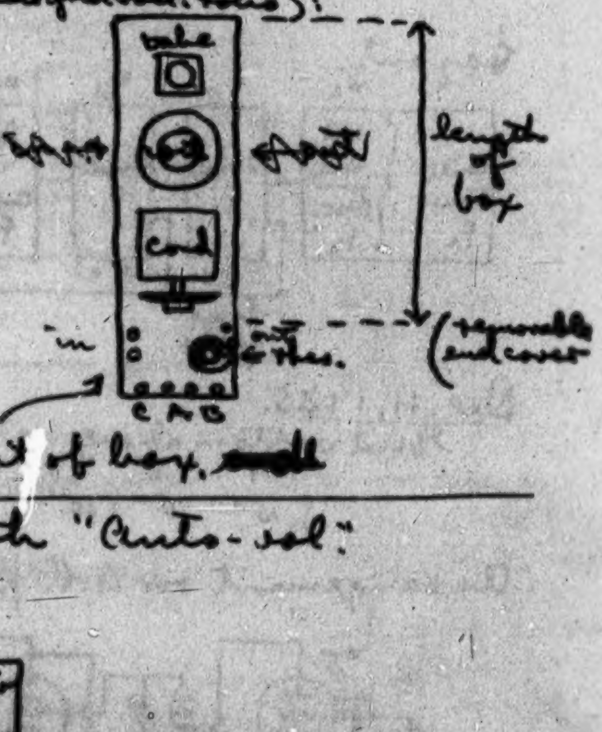


Complete shielded unit:



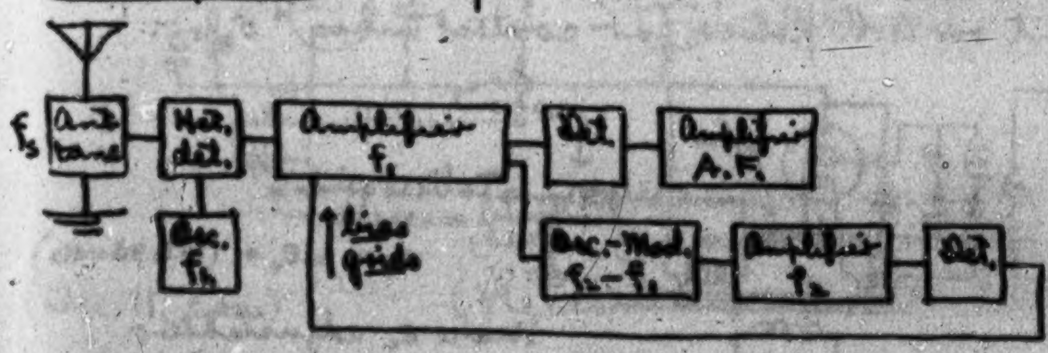
Capacity Bridge form (better with Neutroidal Coils):
(variable plate grid volt. ratio):

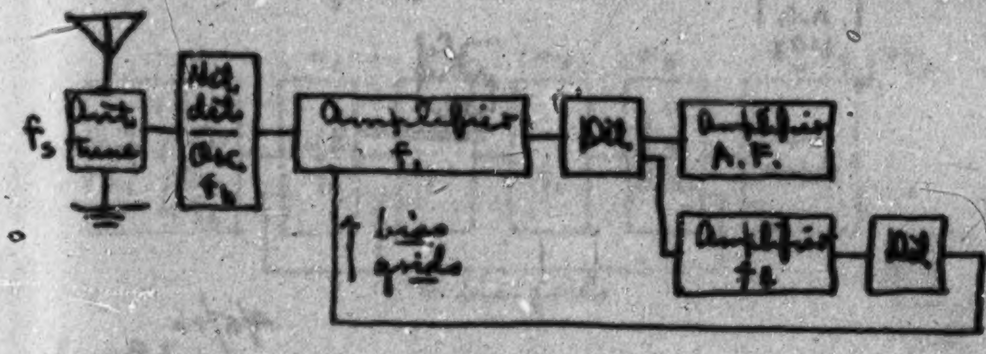




base slides out of box. ~~small~~

Dec. 10, 1925 Super-het. with "Auto-sel."



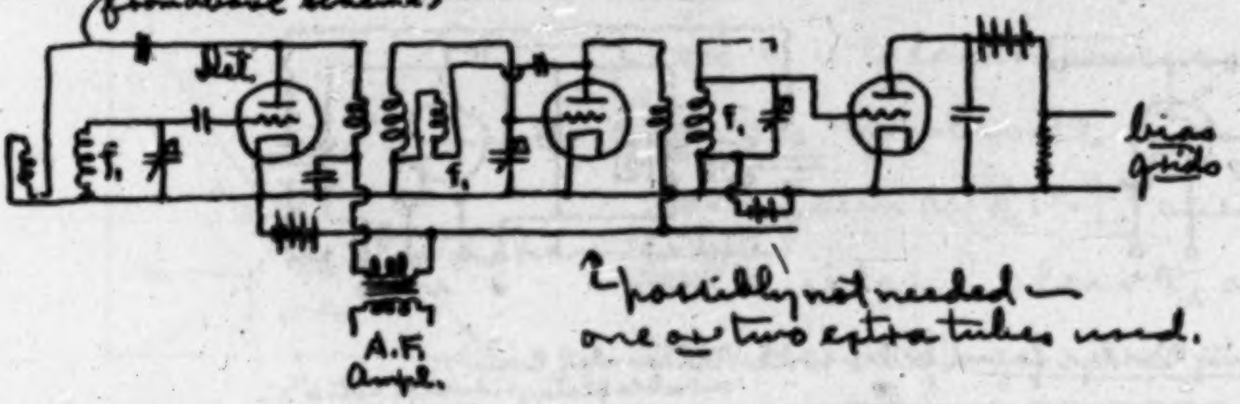


A/5/26
12/18/25
V.E.W.

84

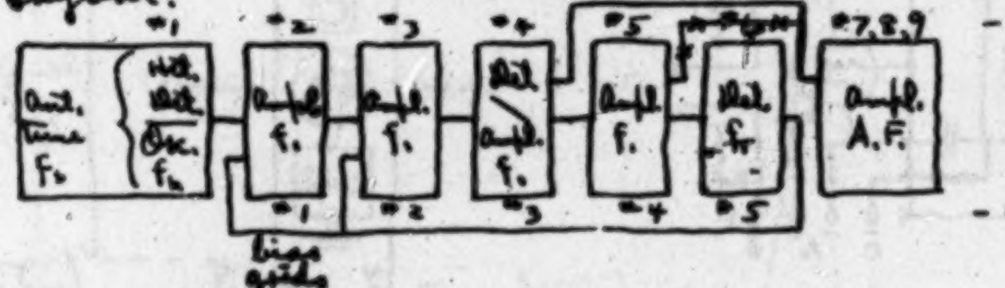
Dec. 10, 1925 (con.) Automatic vol. control with super-het.

(from above scheme)



possibly not needed — one or two extra tubes used.

Layout:



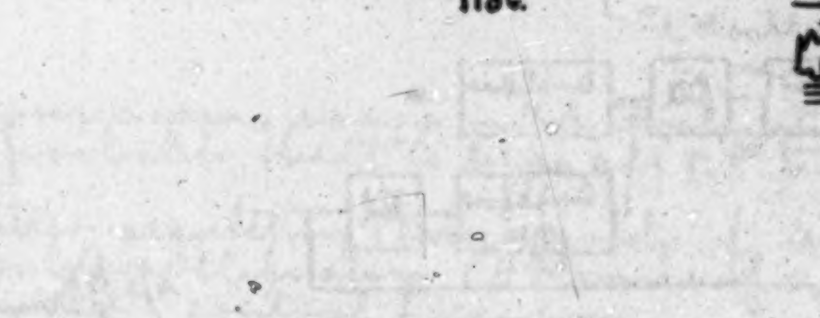
- 9 tubes
  - 3 r.f. amp.
  - 1 det.
  - 2 vol. control
  - 3 a.f. amp.
- 5 shielded boxes.

Dec. 11, 1925.

Grid volts in above:

	#1	#2	#3	#4	#5	#6		#7	#8	#9
f_1	10^{-3}	10^{-2}	10^{-1}	1.0	10	100 —	a.f.	1.0	10	100 —

Arrangement on A.C. power for control tubes #5, 6:

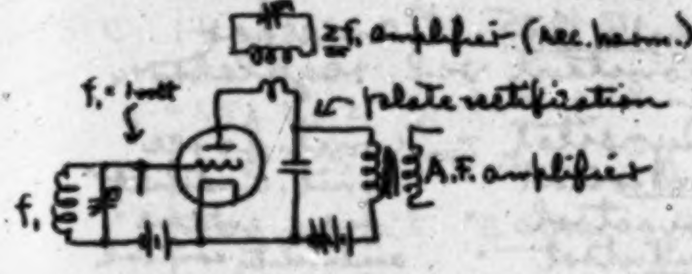


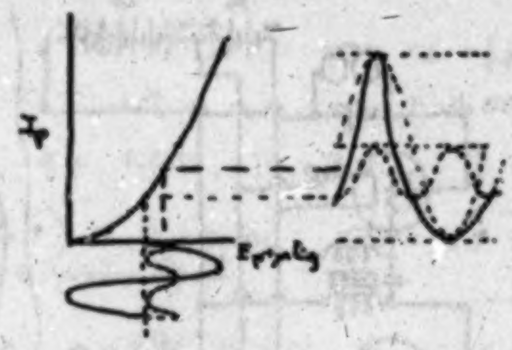
$e_b = \mu e_o + (10 \text{ to } 30 \text{ volts})$

Make e_c adjustable:

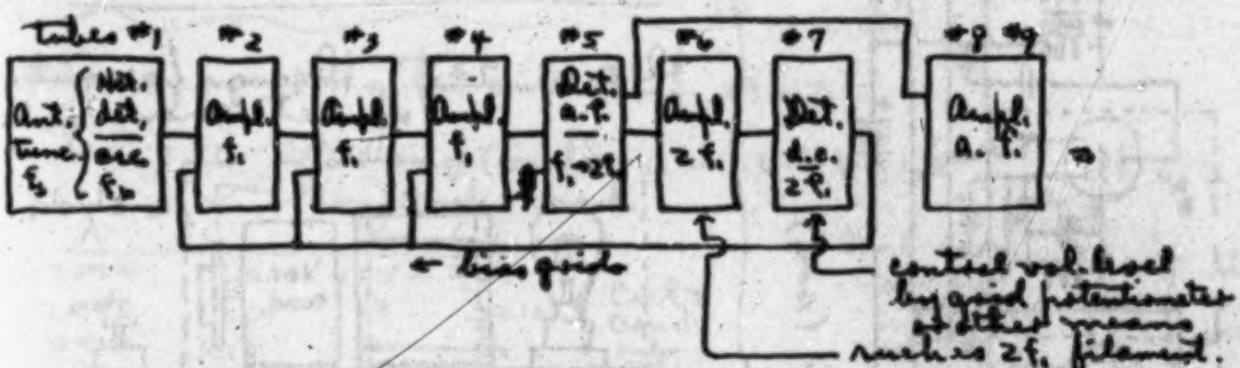
1/5/26
J. F. Dreyer Jr.
12/18/25
V. E. W.

Dec. 10, 1925 Control amplifier on second harmonic

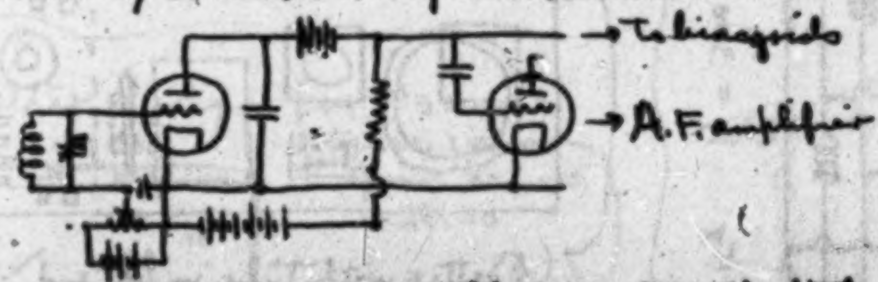


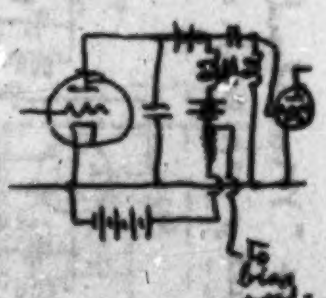


On plate (approx.), 1v. on grid:
f, 8v. (in series only)
2 f, 2v. " " "
a.f. 3v. = $\frac{1}{3}$ = 1v.

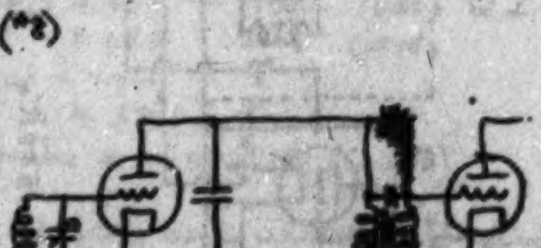


Combining control & signal detectors:





(Dec. 11, con.) (Necessitates extra "B" battery)



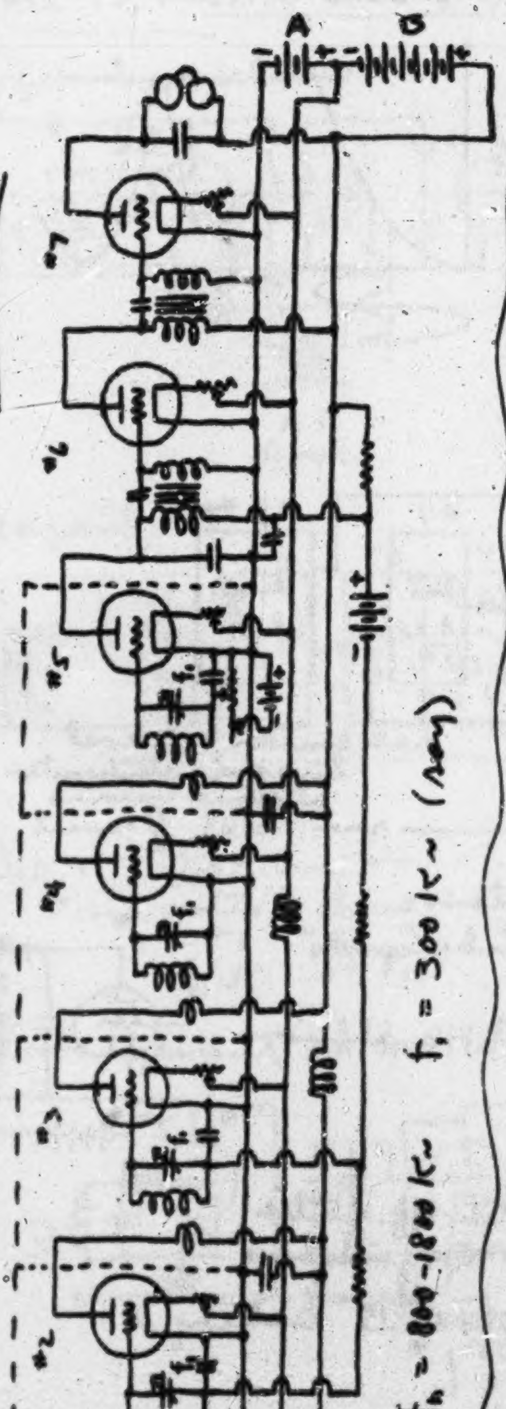
4/5/26
J. F. Dreyer Jr.

12/15/25
V. E. W.

86

"Autosel," or "Monoloud" or "Uniloud" set.
Neutralizing cap. coup. where needed.

Dec. 12, 1925



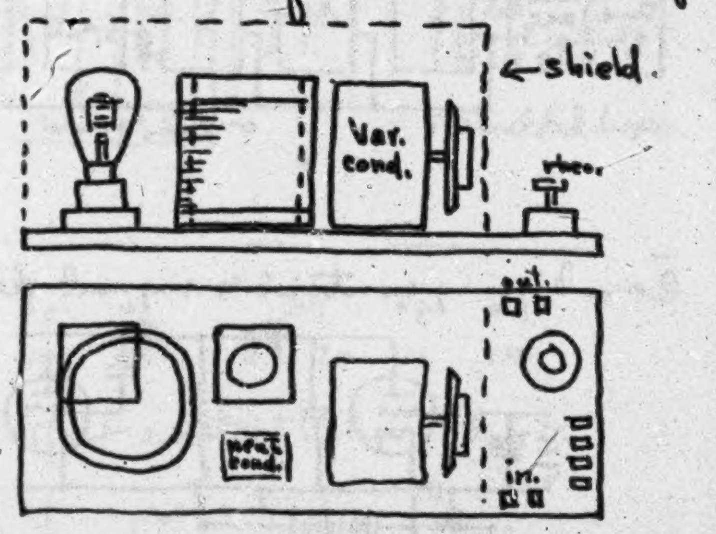
f_s = 500-1500 k~ f_h = 800-1800 k~ f_i = 300 k~ (say)

Dec. 15, 1925 Names for constant vol. regulator.

Dynostat = "const. force"
Audiostat = "const. audibility"
Dynatrol = "force control"
Audiotrol = "audibility control"
Amplitrol = "amplitude control"
Amplistat = "const. amplitude"

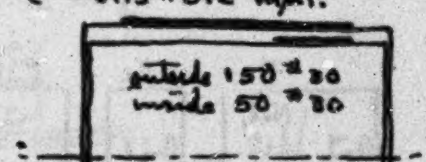
seem best ones., esp. with Neutrodyne

Dec. 15, 1925 Design for units of set shown at left.



(Better with tube in left end) (or in coil)

Coil: 150 #30 a = 1½" b = 3"
L = 1.5 m.h. R_0 = 14 Ω R_1 = 100 Ω say
ω = 2 (1000 m. = λ) C = 0.15 – 0.2 mmf.
g = .01 m℧
ωL = 3



Neutralization in unit.

4/5/26

Dec. 16, 1925. R.F. resistance computations:

S-C 1-b ckt. $A = 8$ at 600 m. ($\omega = 3$) $\quad T = 12$ approx.

$n = 52$ #22, $a = 1.5$, $b = 2$ } $L = 0.18$ mh. $R_0 = .63\ \Omega$ $\quad \omega L = 0.55$ KΩ

$\mu = 10$, $g_p = .12$ ∴ $T^2 g = 1.7$, $g = 0.012$, $R = 3.5\ \Omega$ $\quad \frac{R}{R_0} = 5.5$

[Same at 200 m. ($A = 16+$): $g = 0.006$, $R = 25$]
(incl. 2×5 prim.)

By comparison: Coil 150 #30, $a = 1.75''$, $b = 3''$, $R_0 = 14\ \Omega$
$R/R_0 = 3$ (say) ∴ $R = 40$ $\quad g = .005$ $\quad \omega L = 3$.
opt. $T = \cancel{8}$ 4.5 $\quad A = \cancel{40}$ 32

Measurements from Aug., 1923:

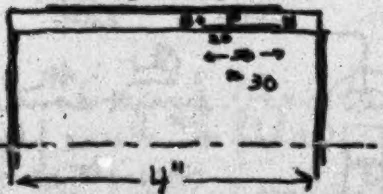
$n = 250$ 10 #38 litz (bank) $a = 1.6''$ $b = 1.3''$ $\quad L = 5.3$ mh.

↓ Gen. Radio cond.

λ	C	R	(g)	
1000	.060	125 Ω	.0013	Coil + cond. only
1500	.120	48	.0010	
2000	.210	31	.0012	
3000	.50	20	.0018	

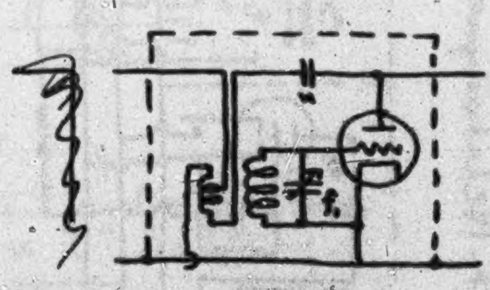
	R	
Coil-cond.	46	etc. at 1500 m.
socket	6	
tube (cold)	12	
Neut. cond. +	16	
bind. posts	54	
	134 Ω	

Better design for #30 coil:



sec. 150
prim. 20 (or 50)
neut. 50

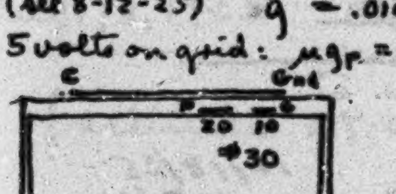
Tap at $\frac{1}{10}$ (15) for tests.
[also $\frac{1}{2}$ (75)]

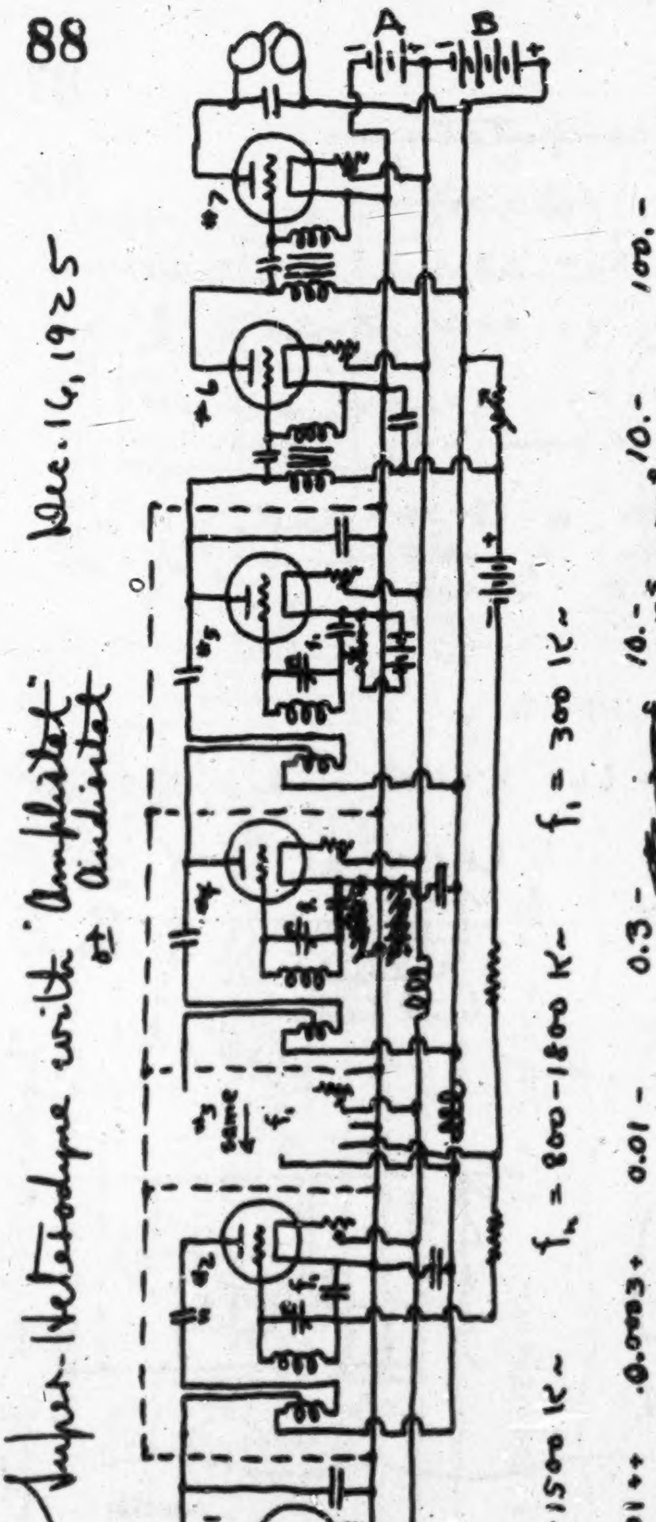


Oscillator design: $\quad$ f_n 400 m., $C = 0.250$ $\quad$ 750 $\quad$ needed: (850) K$\sim$
∴ $L = .18$ mh. $\quad$ 150 m., $C = 0.035$ $\quad$ 2000 $\quad$ (1800)

$L = \frac{a^2 n^2}{9a + 10b}$ $\begin{pmatrix} a = 1.75 \\ b = 3 \end{pmatrix} = \frac{.067}{10^3} n^2 = .18$ $\quad n^2 = 2700$
$n = 52$ (in 3")
make $n = 50$ #18 (in 2.5")

(see 8-12-25) $\quad g = .010$ to $.003$, (say .010)
5 volts on grid: $\mu g_p = 0.5 +$ ∴ 5 + 10 (grid + plate) coils needed (affecting) (turns)
(say 10 + 20)

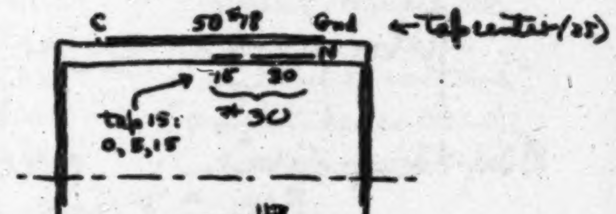


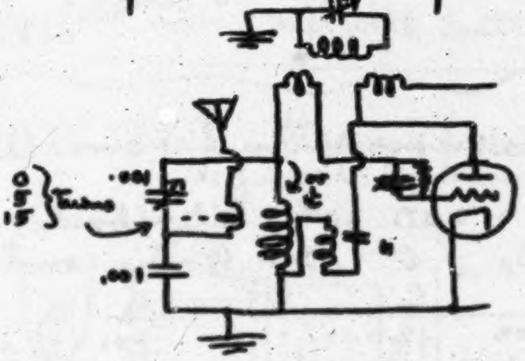


Dec. 16, 1925

Antenna ckt. design:

600 m. .500+ mμf. } L = 0.180 mh.
200 m. .060

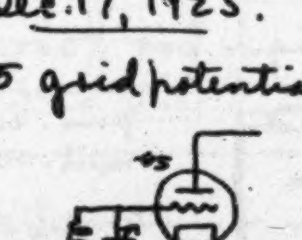




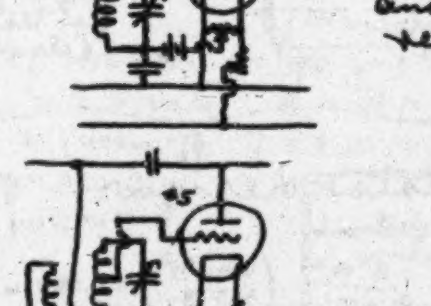
Neutralize to plate ckt. only (osc. grid coil shunted)

Dec. 17, 1925.

#5 grid potential control:



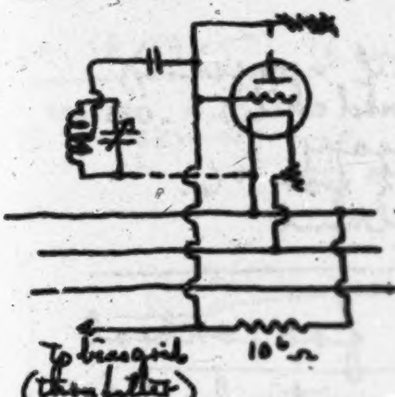
Q.5: omit control and use plate resistance only

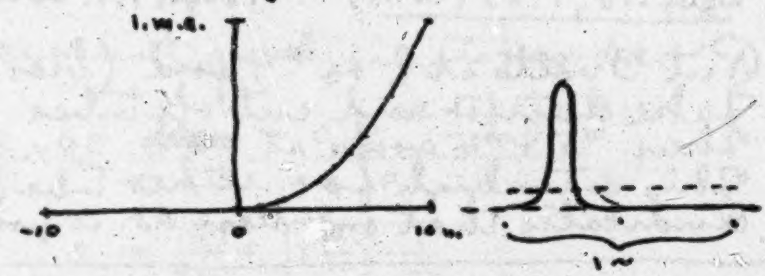


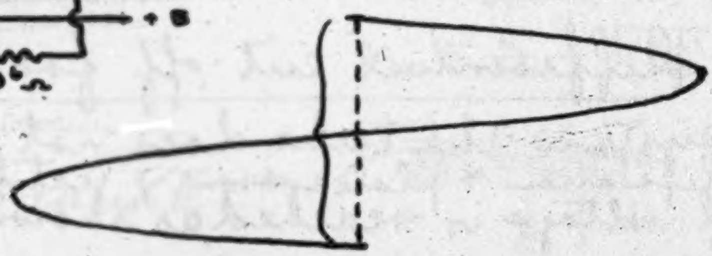
8/5/26 J. T. Dreyer Jr.

12/18/25
H. S. W.

Dec. 17, 1925. Separate rectifier tube for control

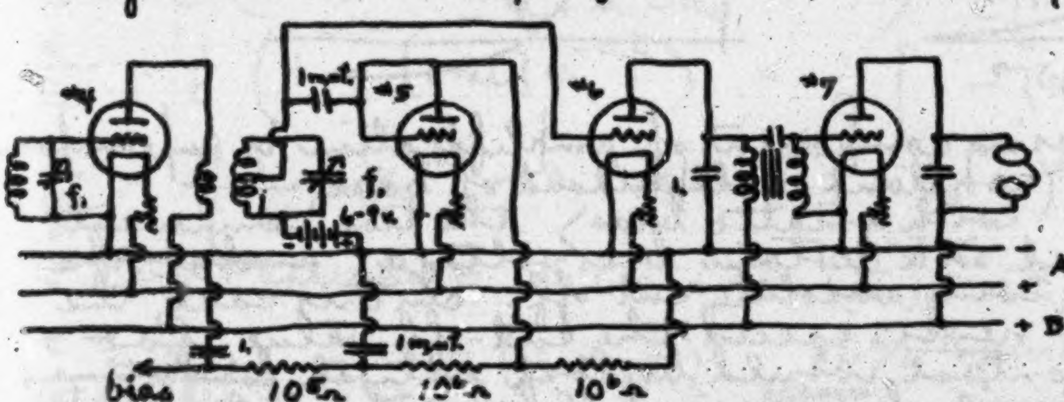






$\tau_{equiv.}$ mean
$g' = .01$ mv
(12 volts a.c.)
(10 volts bias)

Complete cut-off of amplifier obtained at about 10 volts a.c. (r.f.) on rectifier tube, so design a.f. detector to operate on 10 volts max., and regulate a.f. amplifier accordingly:



{ #6 grid bias better controlled by potentiometer across #6 filament, in series with 9 v. "C" battery.

{ Cut-off controlled by #5 rheostat (better to use 199 tube, low E_f)

~~R.F. (f_1) amplification~~

		f_1					a.f.
Grid volts (approx.):	#1	#2	#3	#4	#5	#6	#7
a.c.	.0001	.003	0.1	3	10	10 v.	10 v.

Dec. 18, 1925 It seems desirable to determine the max. r.f. voltage possible, and then to utilize it to best advantage, since it facilitates a.f. amplification & control of r.f. ampl.

12/18/25.
O. E. W.

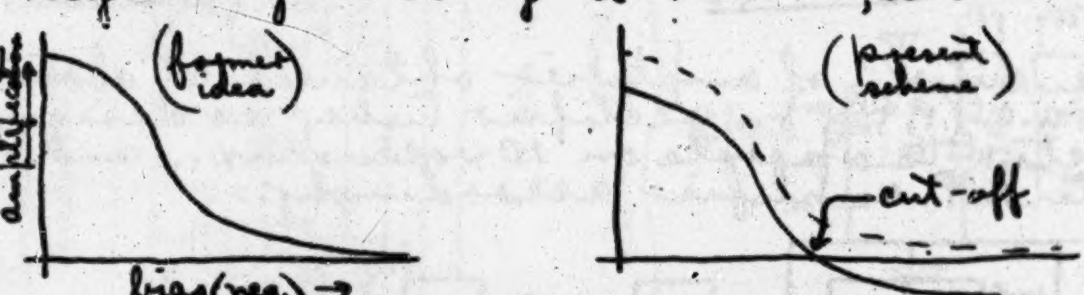
90

Dec. 18, 1925 (con.) High r.f. voltage

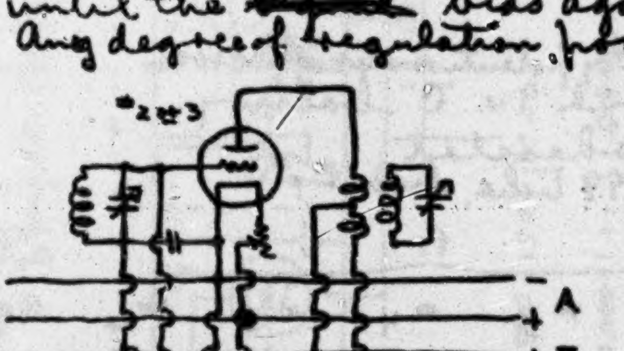
Put 3 volts at f. on #4 grid (bias by cond. if necessary).
Take detector and cut-off tubes load (cond ckt.) = .02 mv
Then #5 & #6 grids at 30 v. if necessary.
This is too high for either tube, at least for #6.
Indicates that one-stage A.F. is possible in limit.

Dec. 18, 1925 Differential cut-off for control

In the above systems, the tube does not absolutely cut off (amplification & plate current) until a high negative grid voltage is reached, as shown:



If an opposing component of amplification is superimposed, however, (constant, independent of bias, — or increasing with greater bias) the two components will cancel at a certain bias voltage, ~~and if the operation~~ giving absolute cut-off. In this case, the bias must never exceed the cut-off value, for then the control would be lost entirely ~~for a time~~ until the ~~signal~~ bias again fell below this value.
Any degree of regulation possible by this method.

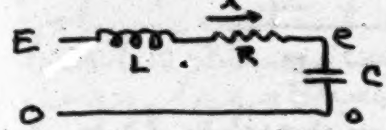


In order to prevent the bias exceeding the cut-off value, it should lag behind the source of control (by inductance & resistance.)

Time constant of control circuit must be less than that of bias filter, or critical bias may be exceeded.

12/18/25
H.E.W.

Dec. 18, 1925 Time lag circuit analysis, to pass d.c.



$$\frac{e}{E} = \frac{1}{C}\left(1 - \frac{a_2 e^{-a_1 t} - a_1 e^{-a_2 t}}{a_2 - a_1}\right)$$

where $a_1 = \frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}}$
$a_2 = \frac{R}{2L} - \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}}$

$$i = E\frac{a_1 a_2}{a_2 - a_1}\left(e^{-a_1 t} - e^{-a_2 t}\right)$$

Does e ever exceed E? *

$e = \frac{1}{C}\int i\,dt \quad \frac{de}{dt} = \frac{i}{C}$

Max.: $\frac{de}{dt} = 0$, $e^{-a_1 t} = e^{-a_2 t}$, then $a_1 t = a_2 t$ $\left\{ \begin{array}{l} t = 0, \text{ or} \\ a_1 = a_2 \end{array} \right.$

Solution for $a_1 = a_2$: Let $a_2 = a_1 + h$

$$\frac{e}{E} = \frac{1}{C}\left(1 - \frac{(a_1+h)e^{-a_1 t} - a_1 e^{-(a_1+h)t}}{a_1 + h - a_1}\right) = \frac{1}{C}\left[1 - \frac{[a_1 + h - a_1(1-ht)]e^{-a_1 t}}{h}\right]$$

$$\frac{e}{E} = \frac{1}{C}\left(1 - [1+at]e^{-a_1 t}\right) = \frac{1}{C}\left[1 - (1+a_1 t)e^{-a_1 t}\right]$$

$$\frac{de}{dt} = \frac{E}{C}\left[-a_1 e^{-a_1 t} + a_1(1+a_1 t)e^{-a_1 t}\right] = 0, \quad t = 0, \infty$$

e never exceeds E so long as $\left(\frac{R}{2L}\right)^2 \geqq \frac{1}{LC}$

$t = \frac{1}{a_1}$: $\frac{e}{E} = \frac{1}{C}\left(1 - \frac{2}{e}\right)$ 26% of max $\frac{e}{E} = 1$
(at max. slope)

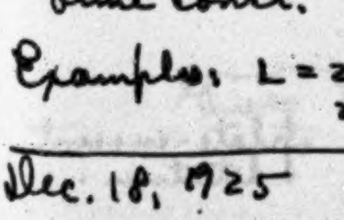
Time const. $= \frac{1}{a_1} = \frac{2L}{R}$ for $\frac{R^2}{4L^2} = \frac{1}{LC}$

Examples: L = 250 h., $\frac{2L}{R}$ = 0.01 sec., R = 50,000 Ω, C = .4 μf.
250 0.001 500,000 0.004

Dec. 18, 1925 Audiostat, continued

Control of "A" tube from detector (with grid cond. & leak):
3 v. max on grid of det. (#5), 20 v. (d.c.) + on plate, (10 v. mod.)

Bias #2 grid by potentiometer (const.) adjustable reducing amplification so that it is cancelled by #2a when about 3 v. on det. grid, making #2a plate 10 v. more positive.
(#2 grid may also be biased by det. grid)
(or by that means only)



→ To plate (prim.) of #2a tube

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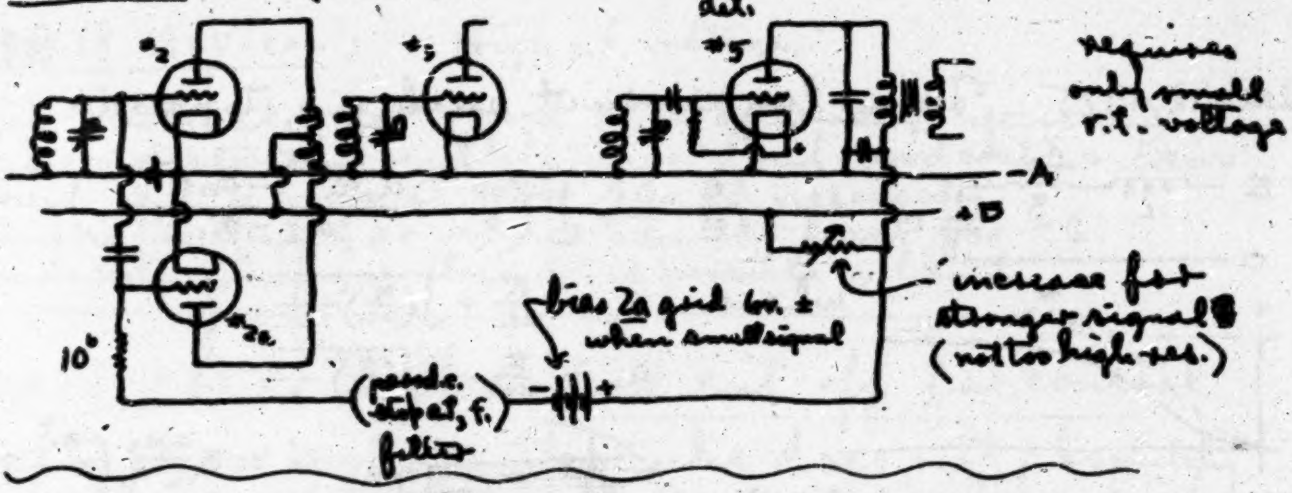
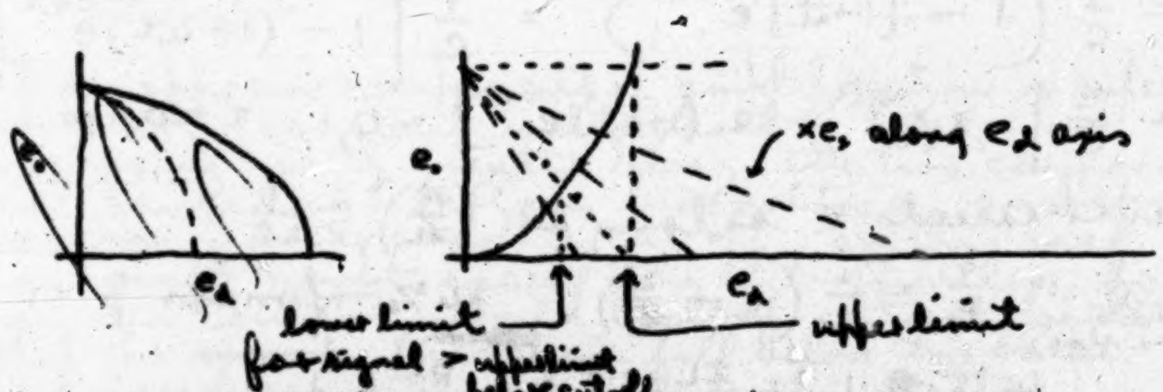
Dec. 18, 1925 (con.) Audiostat

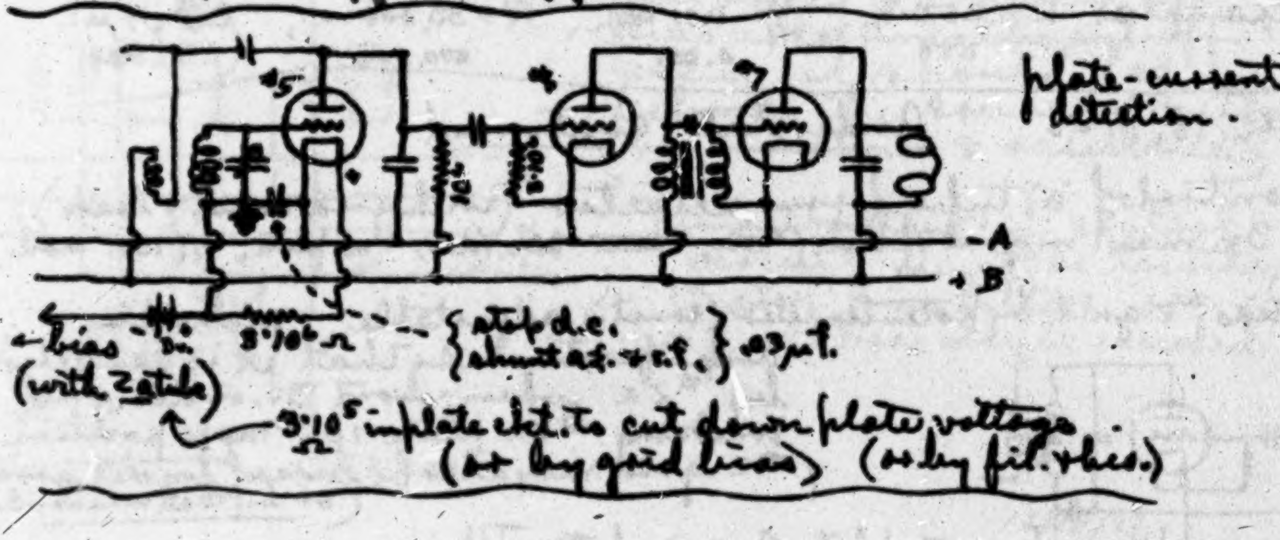


Alternative methods for Audiostat: (examples only)

p. 89 high-voltage rectifier and detector, bias #2, 3.
p. 88 combined det. & rect., med. voltage, bias #2, 3.
p. 90 differential means, bias #2, 3 (either of above)
p. 91, p. 92 " " , comb. det. & rect., 2a tube bias.



Showing cut-off by differential method.

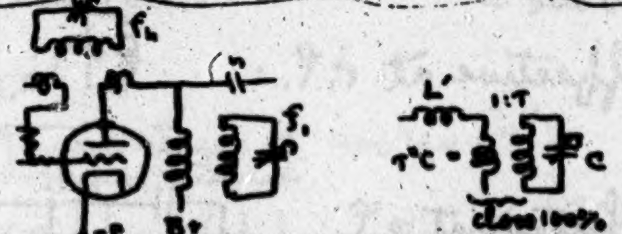


Dec. 19, 1925 (con.) Audiostat:

Since "static" is "completely modulated" as compared with perhaps 50% modulation of a signal, and since the volume control does not respond to short crashes, the best setting would be such that the "static level" was less than the max. signal. This can be done by double adjustments:

1.) Set det. volume control on loud signal
2.) Adjust r.f. amplification to cut down static level to below the voltage required for "control".

Scheme for #1 tube:



In plate ckt.,
f_h coil, L', T^2C } in series (effective)

Make $\omega_h L' - \frac{1}{T^2\omega_h C}$ positive to reduce amplitude of oscillations at high ω_h, where amplitude of f_h is normally high.

$T = 4$, $T^2C = 3.$ mμf. $\omega_h > 4$ /μsec.

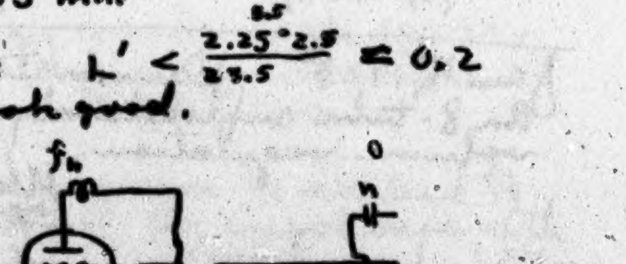
$L' > \frac{1}{T^2\omega_h^2 C} < .02$ mh. $L' > .02$ mh.

But shunted by $< .05$ mμf:
$\omega_h < 12$ $L' < \frac{1}{(12)^2 .05} = 0.15$ mh.

Design p. 87, 50#30 on prim.: $L' < \frac{2.25 \cdot 2.5}{23.5} = 0.2$
Does not look good.

Best scheme in some ways:

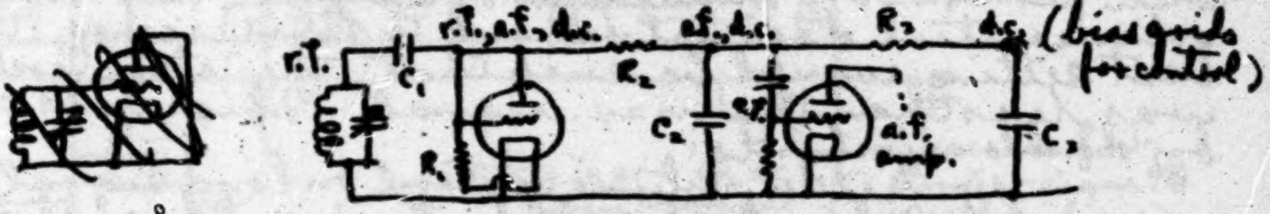
Gives f_h capacitance path to filament.



$\underline{O_1}$ $L' = 0.1$ about, shunt by ~~[illegible]~~ cond. .5 mμf.
(not very good)

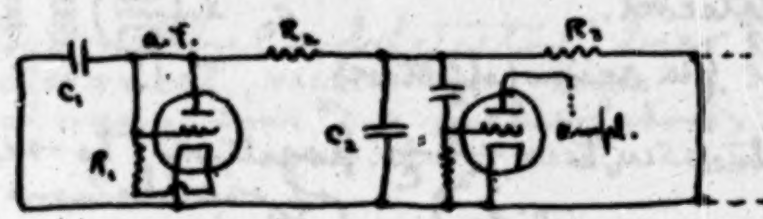
$\underline{O_2}$ smaller prim. (no added elements, or shunt cond.)

94 Jan. 2, 1926. Detector - control scheme



Above -
effective at r.f.:

effective at a.f.:
$R_3 >> R_2$
$\left.\begin{matrix} C_1 \\ C_2 \end{matrix}\right\}$ discharged by $\left\{\begin{matrix} R_1 \\ R_3 \end{matrix}\right.$



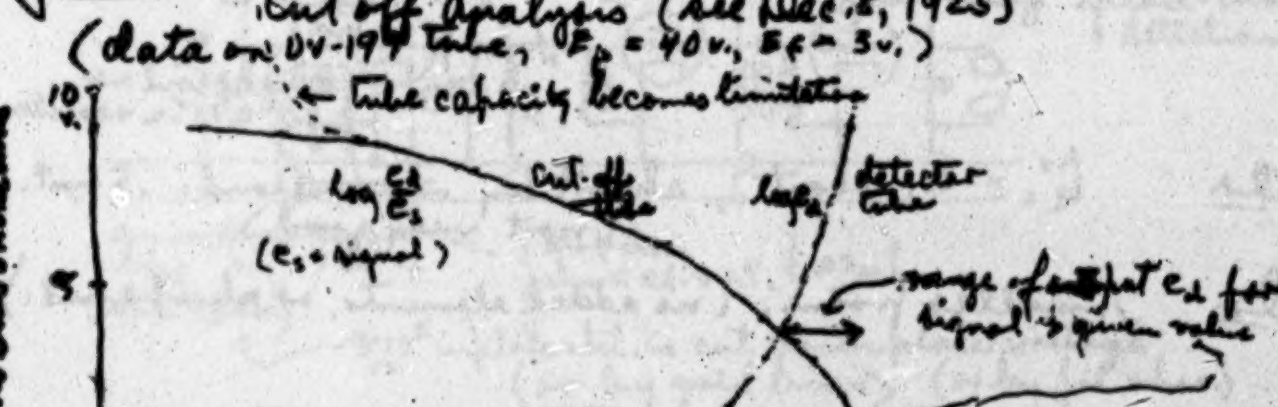
effective at d.c.:
$\left.\begin{matrix} C_1 \\ C_2 \\ C_3 \end{matrix}\right\}$ discharged by R_1
also $\left\{\begin{matrix} C_2 \text{ thru } R_2 \\ C_3 \text{ thru } R_3 \end{matrix}\right.$

Demonstrated to me on 4/5/26 J. F. Dreyer Jr.

Jan. 3, 1926 Demonstration of "Audiostat" or "Amplistat". An 8-tube superheterodyne-neutrodyne set with automatic volume regulation.

Walter A. MacNair Jan. 3, 1926
F. M. Defandorf Jan 3, 1926
V. E. Whitman Jan 3, 1926

Jan. 4, 1926. Cut off analysis (see Dec. 8, 1925)
(data on UV-199 tube, $E_p = 40$ v., $E_f = 3$ v.)

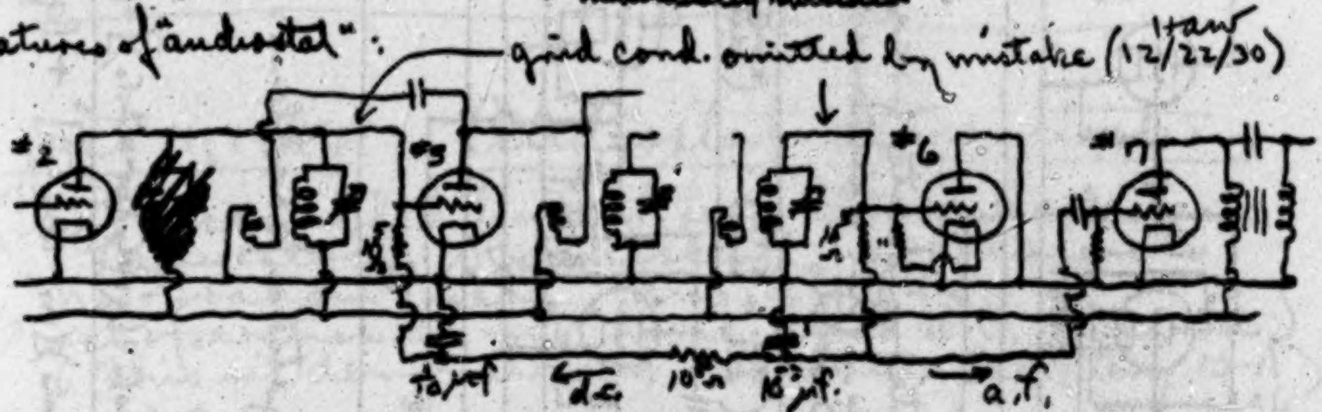


4/5/26
J. F. Dreyer Jr.

Jan. 4, 1926 Outline of set demonstrated ~~[illegible]~~ Jan. 3 embodying preliminary form of "Audiostat".

(#3, 4, 5 are Neutrodyne tuned stages at 300 K~ = f_1) individually shielded

Features of "audiostat":



In this set the volume regulation works with 10 - 20 v. on #6 grid at r.f. (f_1). More amplification is needed to supply this voltage (at least) on all stations.

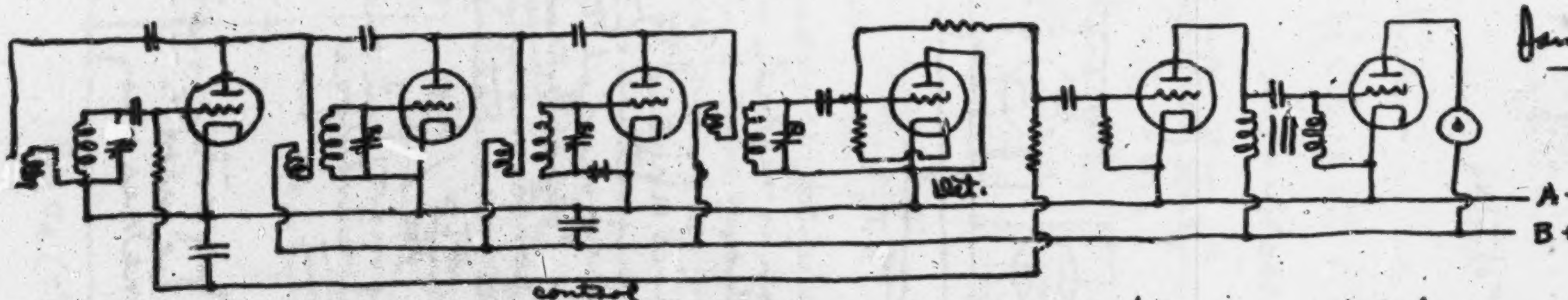
On local stations, about 1 v. ~~[illegible]~~ is applied to #3 grid at f_1 which is so great that the curvature of the $i_g e_g$ curve causes distortion and increased modulation of the r.f. voltage output of that tube. This breaks down the vol. control, which depends on const. modulation within reasonable limits, while here the modulation may be 75% or so. These difficulties $\propto \frac{d^2 I_p}{dE_g^2} \Big/ \frac{dI_p}{dE_g}$.

This would point to advantage of control by more than one tube, though brief tests did not indicate an advantage. This involves a greater variation in the output, i.e. less effective regulation.

When regulation is not effective to great enough degree, the first audio-freq. stage could be used to secure necessary added control. This makes very high degree of control possible.

96

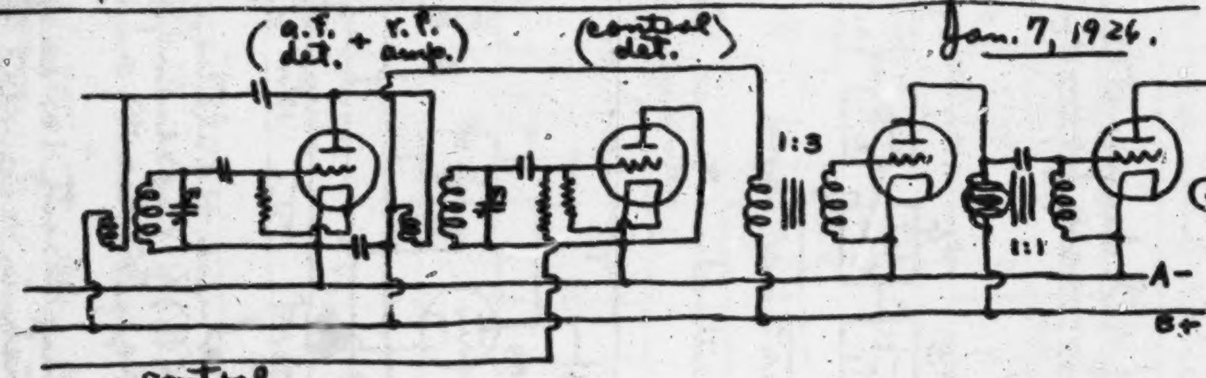
Jan. 7, 1926



This represents arrangement of intermediate freq. amplifier, etc. in set demonstrated Jan. 3, 1926. (All resistances shown were bet. 0.1 and 1 Meg.) Grid voltage of detector up to 20 volts

Jan. 7, 1926.

Modification of above, one more tube and more sensitive.



1/5/26
J. F. Dreyer Jr.

Jan. 7, 1926

Solution of approximate neutralization problem:
(see diagram on next page)

Real component:

$$g_e = \frac{i_g}{e_g} = \frac{-\mu g_p \omega C_0 \omega^2 L_1 C_0 \left[\omega C_0 + (y'+\omega C_0)(m-\omega^2 L_1 C_0)\right] + (g_p+g')\omega^2 C_0^2 \left[(m-1)(m-\omega^2 L_1 C_0) + \omega^4 L_1^2 C_0^2\right]}{\left[\omega C_0 + (y'+\omega C_0)(m-\omega^2 L_1 C_0)\right]^2 + (g_p+g')^2 (m-\omega^2 L_1 C_0)^2}$$

PLAINTIFF'S EXHIBIT NO. 9

August 11, 1926 Condenser Design

S-C. 501 # 25-475 $\mu\mu f.$

23 plates, (22 spaces)

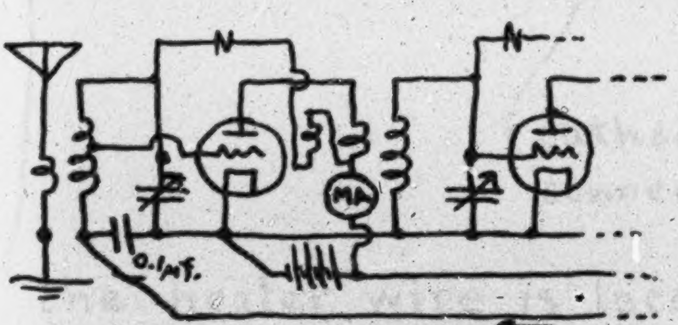
.025" brass plates, .035" spacing.

(20 plates + 20 spaces = 1.2", 20 spaces = 0.7,)

Rotor $3\frac{1}{8}$" diam.; clearance at min.: $\frac{1}{8}$".

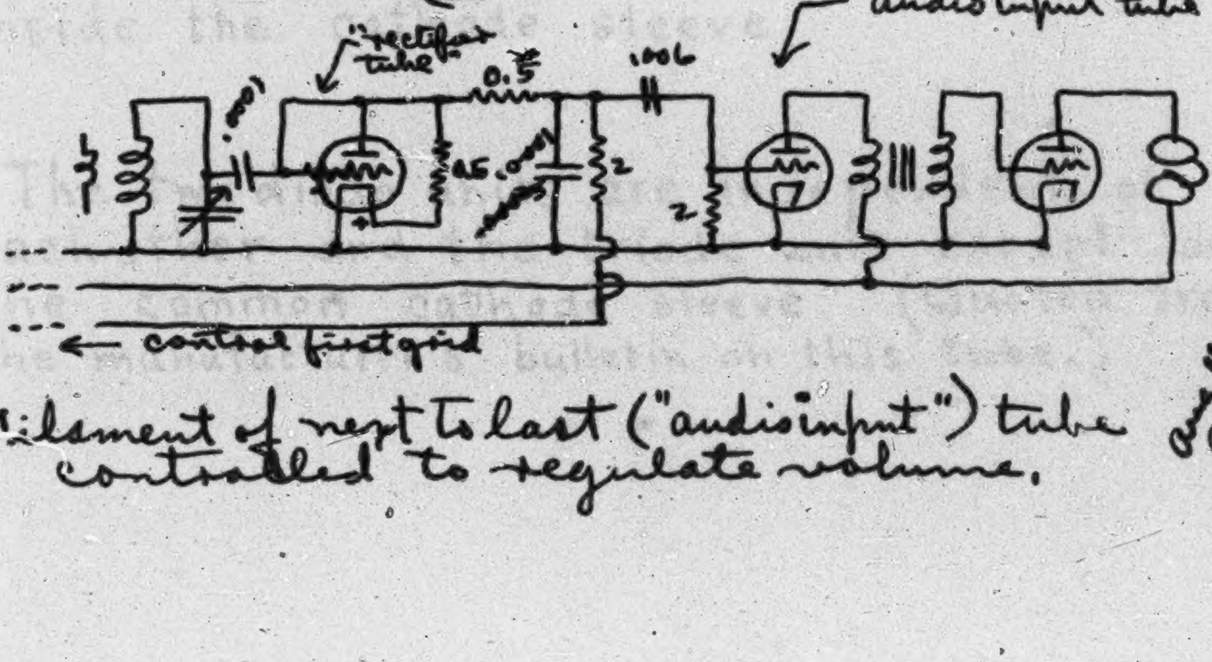
August 11, 1926 Audiostat demonstration

(Set assembled by M. L. Levy, Stromberg-Carlson Laboratory, Rochester. Design to Mr. Graham there, Aug. 2, 1926.
First operation at my home Wash. D.C. Dec., 1925)
(This set demonstrated at Hazeltine Lab., Aug. 10-11 1926)



R.F. Amplifier

To Clement & Millian of L.R.M. 8/11/26



Filament of next to last ("audio input") tube controlled to regulate volume.

Aug. 11, 1926

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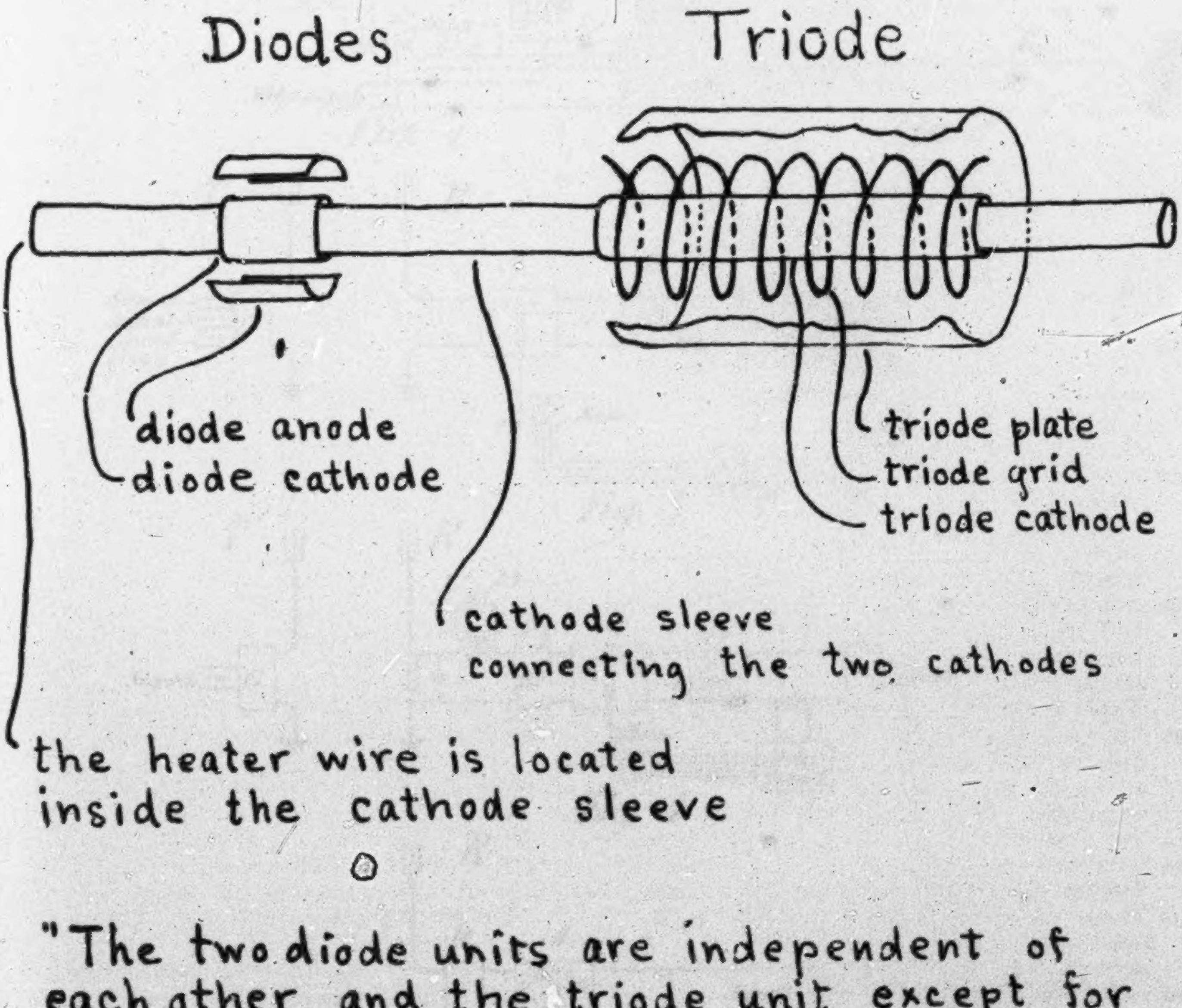
PLAINTIFF'S EXHIBIT NO. 10

The Electrodes of the 75 Tube



"The two diode units are independent of each other and the triode unit except for the common cathode sleeve." (Quoted from the manufacturer's bulletin on this tube.)

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PLAINTIFF'S EXHIBIT NO. 11

Mar. 6, 1923. 1,447,773.

L. ESPENSCHIED ET AL.

RADIOTRANSMISSION CONTROL SYSTEM.

FILED SEPT. 15, 1921.

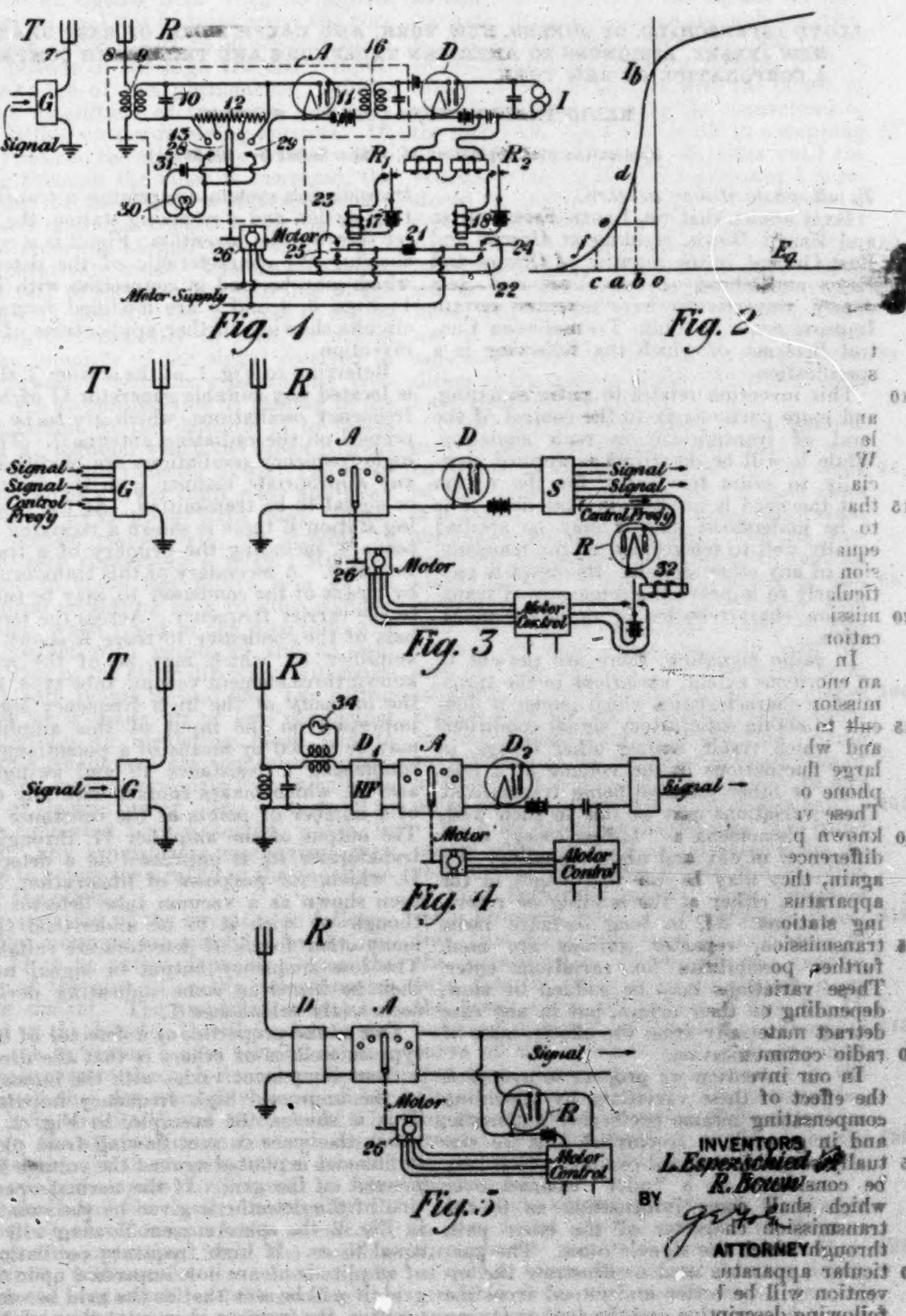


Fig. 1 Fig. 2 Fig. 3 Fig. 4 Fig. 5

Patented Mar. 6, 1923. 1,447,773

UNITED STATES PATENT OFFICE.

LLOYD ESPENSCHIED, OF QUEENS, NEW YORK, AND RALPH BOWN, OF EAST ORANGE, NEW JERSEY, ASSIGNORS TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

RADIO TRANSMISSION CONTROL SYSTEM.

Application filed September 15, 1921. Serial No. 500,881.

To all whom it may concern:

Be it known that we, LLOYD ESPENSCHIED and RALPH BOWN, residing at Queens and East Orange, in the counties of Queens and Essex and States of New York and New Jersey, respectively, have invented certain Improvements in Radio Transmission Control Systems, of which the following is a specification.

This invention relates to radio signaling, and more particularly to the control of the level of transmission in such signaling. While it will be described as applied especially to radio telephony, for the reason that the need is greatest in that field, it is to be understood that it may be applied equally well to telegraphy, or the transmission of any other signals. Its object is particularly to improve the constancy of transmission characteristics in radio communication.

In radio signaling, there are present to an enormous extent, variations in the transmission characteristics which render it difficult to obtain satisfactory signal conditions and which result, among other things, in large fluctuations in the volume of a telephone or other message being transmitted. These variations may be due to such well-known phenomena as "fading away" or to differences in day and night signaling. Or again, they may be due to changes in the apparatus, either at the sending or receiving stations. If, in long distance radio transmission, repeater stations are used, further possibilities for variations enter. These variations may be sudden or slow, depending on their origin, but in any case detract materially from the effectiveness of radio communication.

In our invention we propose to overcome the effect of these variations by providing compensating means, preferably automatic, and in general, to accomplish this we virtually set aside a signal channel which may be considered as a "pilot" channel over which shall come information as to the transmission character of the ether path through which the signals come. The particular apparatus used to illustrate the invention will be better understood from the following description and the accompanying drawing, in which Figure 1 shows a radio transmission system comprising a transmitting station and a receiving station, the latter showing the invention; Fig. 2 is a curve showing the characteristic of the detector which may be used in connection with Fig. 1; Figs. 3, 4 and 5 are modified forms of circuits showing further applications of the invention.

Referring to Fig. 1, at the station T there is located any suitable generator G of high frequency oscillations, which are to be impressed on the radiating antenna 7. These high frequency oscillations are modified in any appropriate manner with the message or signal to be transmitted. At the receiving station R there is shown a receiving antenna 8, including the primary of a transformer 9. A secondary of this transformer, by means of the condenser 10, may be tuned to the carrier frequency. Across the terminals of the condenser 10 there is shown an amplifier 11, which may be of the well-known three-element vacuum tube type, and the intensity of the high frequency signal impressed on the input of this amplifier may be varied by means of a potentiometer comprising a resistance 12 and swinging arm 13, which makes contact with any one of a number of points of the resistance 12. The output of the amplifier 11, through a transformer 16, is impressed on a detector D, which, for purposes of illustration, has been shown as a vacuum tube detector although we wish it to be understood that many other forms of detectors are suitable. The low frequency output or signal may then be heard in some indicating device, such as the telephones T.

One of the properties of a detector of this type as well as of others is that the direct current component varies with the intensity of the impressed high frequency impulses. This is shown, for example, in Fig. 2, in which the space current flowing from plate to filament is plotted against the voltage impressed on the grid. If the normal operation of the detector is given by the point *a* in Fig. 2, the space current flowing will be equal to *ae*. If high frequency oscillations of amplitude *ab* are now impressed upon the grid, it will be seen that as the grid becomes positive, the increase in current through the tube is larger than the corresponding de-

crease when the grid becomes more negative. Consequently, the direct current component flowing through the tube is larger during the reception of signals than when no signals are received, and this increase above the normal space current will be dependent upon the amplitude of the high frequency input. We make use of this phenomenon to indicate the magnitude of the high frequency waves falling on the receiving antenna. If, for any reason, the attenuation of the waves passing through the ether is increased, the amplitude of the waves is correspondingly decreased, and the departure of the space current from the normal value *ae* of Fig. 2 is comparatively small. Use may be made of this fact to increase the gain due to the amplifier 11, and it is our purpose to adjust this gain automatically to such an extent that the intensity of the signal received in the indicator I remains substantially constant. We accomplish this by placing in the output circuit of the detector D to relays R_1 and R_2, through which the direct current component of the detector flows. The relay R_1 is shown as a lower limit relay and relay R_2 is shown as an upper limit relay. These relays control respectively, the circuits 17 and 18, each containing a relay. Mounted adjacent to these last relays is a switch mechanism consisting of a rocking member 21, which, when tilted in one direction, will make contact with points 22 and 23, and when tilted in the other direction, will make contact with points 24 and 25. The tilting member 21 is made up of two conductors separated by an insulating block and to these two conductors are connected, respectively, the supply terminals from a suitable source of electric power. The contacts 22 to 25 are connected to a motor 26, which, in turn, by any appropriate mechanism, may be used to rotate the arm 13 in the one direction or the other.

The operation of the circuit is as follows: incoming messages are amplified by the amplifier 11 to an extent depending upon the setting of the arm 13 on the potentiometer or gain control. The amplified output impressed on the detector D will produce a signal in the indicator I of a certain volume. The space current through the relays R_1 and R_2 is such that for normal volume neither of the local circuits 17 and 18 is closed. If, however, the attenuation in transmission is such that the signals arriving at the detector D are weak, the space current will be relatively small and the lower limit relay R_1 will permit the closing of the circuit 17. This circuit, operating upon the rocking member 21, will connect the motor supply through the contacts 22 and 23, causing the motor 26 to turn in such a direction as to step up the arm 13, thereby increasing the gain of the amplifier 11. This stepping up of the gain will continue until the increase in the direct current component through the relay R_1 is sufficient to open the circuit 17. In case the intensity of the signals becomes too high, the space current through the relay R_2 will be sufficient to close the local circuit 18, which will then tilt the member 21 in a direction to make contact with the points 24 and 25, thereby reversing the connections to the motor 26. This will result in a stepping down of the gain of the amplifier until the volume of the signal at the indicator I is restored to normal. We have thus provided a system which will automatically adjust itself for variations in the transmission characteristics of the system as a whole in such a manner as to maintain a uniform transmission level, and in this we have virtually made use of the carrier oscillations of the message as a "pilot" to indicate the state or condition of the ether through which the waves have been transmitted.

Under extreme conditions of variation it may be that the potentiometer arm 13 may be moved to one extreme limit or the other of the potentiometer 12, and for such cases it is frequently desirable to have notification through some alarm system. For the purposes of illustration we have shown such an alarm system in Fig. 1, consisting of two contact points 28 and 29 in parallel with each other and in series with a lamp 30, and battery 31 which then connects with the arm 13. The contacts 28 and 29 would be so adjusted in position that the arm 13 makes contact with the one or the other upon reaching one extreme position or the other. While we have shown the indicator as consisting of a lamp 30, it is obvious that this may be any other suitable alarm device, such as a bell.

We have described the detector D as being one in which there is an increase in the direct current component during the reception of high frequency signals. Such detectors may, however, work in the opposite direction, this depending upon the curvature of the characteristic. In the case of a vacuum tube detector, it is usual to operate it on the lower curve, as shown in Fig. 2. If, however, it should be operated on the upper curve of this characteristic, it is apparent that there would then be a decrease in the direct current component, this decrease being greater as the intensity of the signal increased. In this event, it would obviously be necessary to reverse the connections for the motor 26.

One of the advantages of using the change in the direct current component flowing through the particular detector described, as well as other detectors, is that the power available from this source is in general greater than that of the low frequency signal obtained from detection. Also this change in direct component is not subject to as

great fluctuations as the message current and therefore apparatus controlled by such change in direct current component is more certain in operation.

A modification of the method used in Fig. 1 is shown in Fig. 3. In this case, instead of using the carrier frequency as a pilot to indicate the condition of the ether, we propose to modulate the carrier frequency with some suitable lower frequency, thus setting aside a signal channel for pilot purposes. The intensity of this special signal, when received, may be used to control the amplification. In Fig. 3, T again represents the transmitting station with the antenna of which is associated a generator G. The high frequency oscillations may be modulated with respect to one or more signal frequencies or multiplex purposes, as is well understood in the art, and at the same time is modulated with some control frequency. The receiving station R includes an amplifying and gain control mechanism shown conventionally at A, this including, for example, the portion of the circuit included in the dotted lines and indicated A in Fig. 1. The amplified output is impressed on a detector D in the output circuit of which may be connected appropriate networks S for separating the plurality of signals from each other and from the control frequency. The control frequency may be passed to a rectifier R in series with which is a relay 32, which, through its front and back contacts, is adapted to control the motor 26, this in turn operating the gain control in the one direction or the other as described in connection with Fig. 1.

The control frequency may obviously be varied over a wide range but in general it will be desirable to have this outside the frequency ranges of the signals to be transmitted. If, for example, one of these signals is a telephone signal and the other is a telegraph signal, it would be convenient to give the control frequency some value, such as 5,000. In this modification, the control frequency becomes the pilot channel to indicate the condition of transmission and operates to step up or step down the gain control in accordance with the conditions it may have encountered in arriving at the station R.

Fig. 4 shows a further modification of the invention, in which the high frequency message received at the station R is stepped down by the detector D_1 to some intermediate frequency lower than the carrier frequency and, in general, higher than the speech frequencies, this latter being accomplished by impressing in series on the input of the detector D_1 the received high frequency and locally generated oscillations from a generator 34. The output from the high frequency detector D_1 may then be impressed upon an amplifier A with gain control of the same form as indicated at A in Fig. 1. The amplified output may then be impressed on the low frequency detector D_2 and, through a motor control mechanism of the form shown in Fig. 1, may be used to control the motor which, in turn, operates the gain control.

It is possible to receive the incoming high frequency message directly on a detector and follow this by amplification, as illustrated in Fig. 5. In this case, there is shown bridged across the output of the amplifier which goes directly to the indicator a circuit containing a rectifier R, the output of which, through a motor control device, is able to control the motor 26 in a manner heretofore described. If the volume of transmission level of the signal passing to the indicator I is below normal, there will be a corresponding decrease in the output of the rectifier R, which will then operate the amplifier A. If, however, the incoming waves are of high amplitude, the increased output of the rectifier R will operate in a compensatory manner on the amplifier A.

In using the term "detector" herein, it is to be taken in a broad sense, as including any device which upon reception of high frequency signals will produce a rectified effect, either electrical or mechanical. It may, for example, be a thermo-junction detector or a hot wire detector in both of which cases a direct current component is produced, dependent on the amplitude of the received high frequency waves. On the other hand the detector may be a hot wire device in which the average change in dimensions depends on the average amplitude of the high frequency waves, and as the mechanical rectified effect varies it may be used to open or close auxiliary circuits to control the amplifier gain in a manner described in connection with various figures. Again, it may consist of a dynamometer of well known forms such as that shown in patent to Fessenden, 706,735 of August 12, 1902, the rectified effect being here a mechanical effect which may be used to open and close a circuit. Such a device may obviously be attached to the receiving circuit either ahead of or after the amplifier.

We would not, however, place too much emphasis on the nature of the detecting device but rather on the designation of a radio signal channel to give information as to the transmission character of the signal path. Any means, then, which will indicate the intensity of the incoming waves and control the amplifier gain may be used.

While the invention has been described as operating at the receiver on that receiver, other methods of raising or lowering the transmission level may be used. For example, in case of two-way signaling in which

there is a transmitting and a receiving equipment at each station a low volume at a receiver, indicating poor transmission, could be used also to cause the output of more energy from the transmitter at that station, thus raising the transmission level for the return message.

The variations which we have described are for illustrative purposes only. It is to be understood that many other variations may be made in the circuit arrangements, or in the details of the motor control and gain control, all of which variations may be made without departing from the spirit or scope of this invention as indicated in the following claims.

What is claimed is:

1. In radio signaling, the method of maintaining a uniform transmission level, which consists in varying the amplification of the receiver to compensate for transmission variations.

2. In a radio signaling system, the method of maintaining a uniform transmission level which consists in using a radio signal channel as a pilot to indicate the transmission character of the transmitting medium and causing this indication to operate on the terminal station apparatus to increase or decrease the power accordingly.

3. In a radio signaling system comprising a detector, the method of maintaining a uniform transmission level, which consists in causing the change in average current through the detector to vary the amplification of the signal.

4. In radio signaling, the method of maintaining a uniform transmission level, which consists in amplifying the incoming signal, impressing the amplified signals on a detector, and causing the variations in average detector currents due to transmission changes to vary the amplification accordingly.

5. In a radio receiving system, means for adjusting the transmission level of the received signal, said means being responsive to changes in the transmission character of the transmitting ether medium.

6. In a radio receiving circuit comprising a detector, means associated therewith responsive to the intensity of the incoming signal for maintaining a unform transmission level for the signals.

7. In a radio receiving circuit comprising a detector and an amplifier, means associated therewith responsive to the intensity of the incoming signal for changing the gain of the amplifier.

8. In a radio receiving circuit comprising a detector and an amplifier, means associated therewith responsive to changes in the transmitting character of the transmitting ether medium and adapted to maintain uniform transmission level.

9. In a radio receiving circuit comprising a detector and an amplifier, means associated therewith responsive to the detector for changing the gain of the amplifier.

10. In a radio receiving circuit comprising a detector and an amplifier, means associated therewith responsive to the changes in the direct current component of the detector for changing the gain of the amplifier.

11. In a radio receiving circuit comprising an amplifier and a vacuum tube detector, means responsive to the average space current through the detector for changing the amplification of the amplifier.

12. In a radio receiving circuit comprising an amplifier and gain control therefor, and a vacuum tube detector, means responsive to the average space current through the detector for changing the gain control in accordance with variations in the transmission level.

In testimony whereof, we have signed our names to this specification this 13th day of September, 1921.

LLOYD ESPENSCHIED.
RALPH BOWN.

Sept. 25, 1923. **1,468,687**

H. A. AFFEL

TRANSMISSION REGULATION

Filed May 4, 1922 **2 Sheets-Sheet 2**

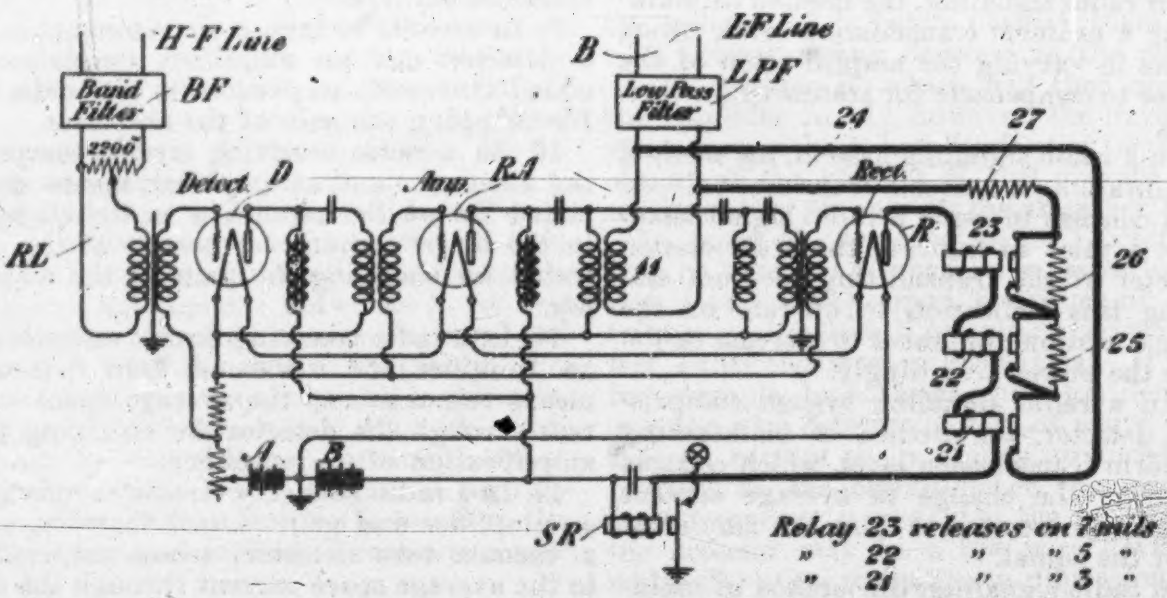


Fig. 3

INVENTOR.
H. A. Affel

BY *G. E. Folk*
ATTORNEY

Sept. 25, 1923. 1,468,687

H. A. AFFEL

TRANSMISSION REGULATION

Filed May 4, 1922 2 Sheets-Sheet 1

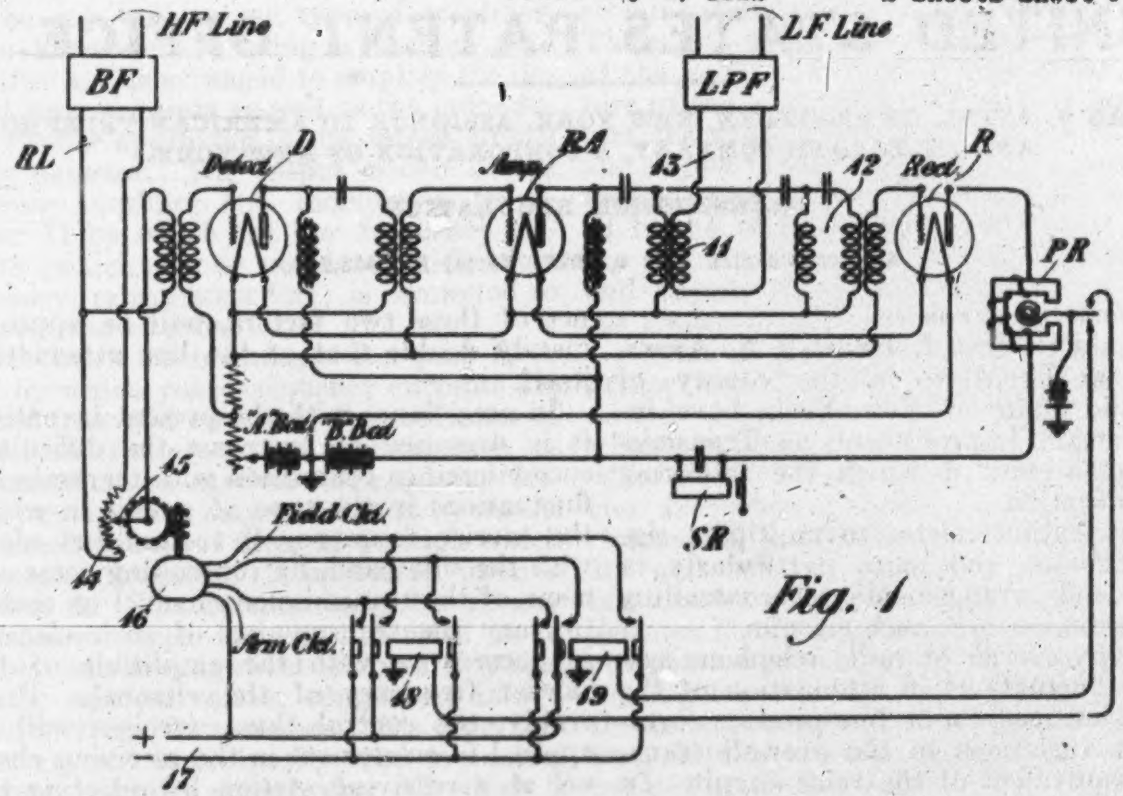


Fig. 1

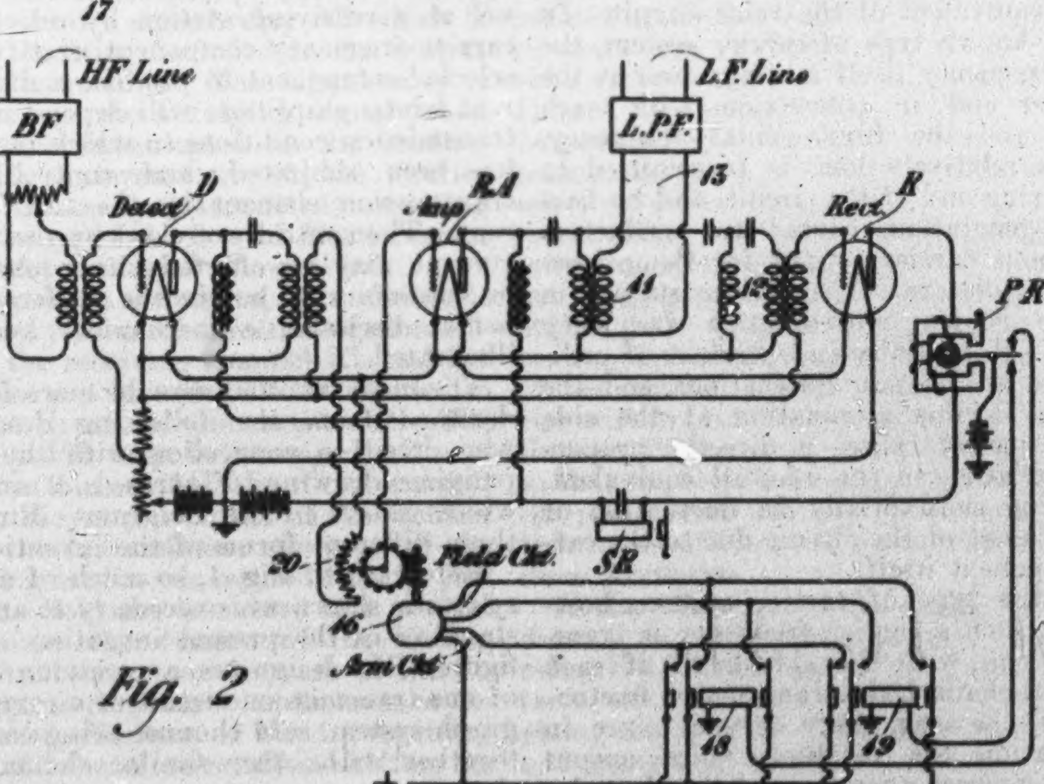


Fig. 2

INVENTOR.

H. A. Affel

BY

ATTORNEY.

Patented Sept. 25, 1923. 1,468,687

UNITED STATES PATENT OFFICE.

HERMAN A. AFFEL, OF BROOKLYN, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

TRANSMISSION REGULATION.

Application filed May 4, 1922. Serial No. 558,447.

To all whom it may concern:

Be it known that I, HERMAN A. AFFEL, residing at Brooklyn, in the county of Kings and State of New York, have invented certain Improvements in Transmission Regulations, of which the following is a specification.

This invention relates to multiplex signaling circuits, and more particularly to methods and arrangements for controlling the transmission over such circuits.

In a wire carrier or radio telephone system, the fluctuations in attenuation of the transmission medium or line produce corresponding variations in the over-all transmission equivalent of the voice circuit. In one well known type of carrier system, the carrier frequency itself is suppressed at the modulator end in connection with each channel, and the fundamental frequency, which is relatively low, is transmitted to the receiving end of the circuit, and by harmonic regeneration, caused to produce a synchronous carrier supply for the respective demodulators. The carrier supply in this case is transmitted at a frequency which is substantially independent of ordinary line attenuation fluctuations and the variation in line attenuation at the side band frequency causes a directly proportional variation in the over-all equivalent, there being substantially no fluctuation of the equivalent of the circuit due to the carrier component itself.

With the type of carrier system, however, in which a carrier frequency is transmitted along with the side band of each individual channel, the transmission fluctuations may be even more serious, since in demodulation the resultant voice output may, for normal operation of the demodulator, be proportional to the product of the carrier and the modulated side band. If, therefore, the attenuation of the intervening line or other transmission medium varies, approximately the same variation will take place for both the carrier and the modulated side band, and the resultant voice circuit variation, being proportional to the product of these two factors, will be approximately double that of the line attenuation itself.

In accordance with the present invention, it is proposed to overcome the difficulties encountered in connection with transmission fluctuations in the type of circuit in which the carrier frequency is transmitted along with the side band, by controlling some element of the transmission channel or circuit to vary the transmission of such element in accordance with the amplitude of the carrier frequency of the channel. Preferably, the control thus exercised will be applied to an element in the receiving channel at a receiving station by selecting the carrier frequency component, rectifying the selected component to produce a direct current whose amplitude will depend upon the transmission conditions to which the carrier has been subjected, and controlling the transmission element by the rectified current. The control exercised by the rectified current may be effected either electrically or mechanically, but in the preferred form herein disclosed, a mechanical system is illustrated.

The invention may now be more fully understood from the following description, when read in connection with the accompanying drawing, Figures 1, 2 and 3 of which show circuit diagrams illustrating three different forms of the invention.

Referring to Fig. 1, so much of a carrier system is shown as is necessary to an understanding of the present invention. In this figure, RL designates a receiving channel of one transmission circuit of a carrier telegraph system, said channel being connected, together with other similar channels (not shown) to a common transmission line (not shown) over which carrier frequencies are transmitted. The corresponding transmitting channel is not illustrated, as it is not involved in the present invention. The receiving channel RL includes a band filter RF for selecting the desired side band and the corresponding carrier, a detector D and a receiving amplifier RA. The detector D

may be of any well known type, such as a vacuum tube detector, and is adapted to detect the voice currents corresponding to the side band by beating the side band with the carrier. The receiving amplifier RA may be any well known type of amplifier, but is illustrated as being a vacuum tube amplifier and is arranged to amplify the detected voice currents as well as the unmodulated carrier appearing in the output circuit of the detector. The output circuit of the receiving amplifier RA includes a transformer 11 by which the low frequency circuit 13 (which may be associated with a low frequency transmission line) is connected to the receiving channel.

The circuit 13 includes a low-pass filter LPF by which voice frequency currents are selected into said circuit to the exclusion of the higher frequency components such as the unmodulated carrier. The carrier frequency component may be selected by means of a tuned circuit or filter 12 through which the carrier frequency is impressed upon a rectifier R. The rectifier may be of any well known type but is illustrated as a vacuum tube arrangement adapted to translate the selected carrier component into a direct current. In systems of this type, this direct current is ordinarily used to control the operation of a signal relay SR which is illustrated as being included in the output circuit of the rectifier. This signal relay is adapted to operate a ringing signal when the carrier is interrupted at the sending station, the interruption of the carrier (which is normally transmitted) resulting in the cessation of the flow of direct current in the output circuit of the rectifier.

In the present invention, this circuit is also utilized to control the transmission efficiency of the receiving channel RL and for this purpose a polar relay PR is included in the output circuit of the rectifier R. The polar relay PR may be arranged with its armature so biased that the direct current flowing in the output circuit of the rectifier R, when the transmission efficiency of the transmitting medium is normal, will be just sufficient to hold the armature at a neutral point against the tension of the biasing means. An increase or decrease in the direct current, in response to an increase or decrease in the efficiency of the transmitting medium, will therefore result in shifting the armature to its upper or lower contact.

In order to adjust the transmission efficiency of the receiving channel RL, the potentiometer 14 is included in the receiving channel upon the input side of the detector D. This potentiometer may be adjusted by means of an arm 15 which may be rotated by a motor 16. The motor 16 may be energized from the power mains 17 and its circuits are controlled by means of relays 18 and 19, so that when either of these relays is operated, the armature circuit is closed, and when one of the relays is operated, the field circuit is completed in one direction, while when the other relay is operated, the field circuit is completed in the opposite direction. These relays are controlled by the contacts of the polar relay PR, so that if the armature of the polar relay is shifted to one contact, the motor 16 will rotate in one direction and adjust the potentiometer to increase the transmission, while if the armature is shifted to the other contact of the polar relay, the motor rotates in the opposite direction and adjusts the potentiometer to decrease the transmission.

Assuming that the carrier frequency, together with the side band, is being transmitted over some transmitting medium whose transmission efficiency varies under different conditions, the side band and carrier frequency assigned to the receiving channel RL will be selected by the band filter BF and will be transmitted from the potentiometer 14 to the input circuit of the detector D. The detector D detects the voice currents corresponding to the side band by beating the side band with the carrier, and the detected voice currents, together with the unmodulated carrier component, are impressed upon the amplifier RA. When these currents are amplified the low frequency voice currents pass through the transformer 11 and the low-pass filter LPF to the low frequency line. The carrier frequency component, however, is selected by the filter or selecting device 12 and impressed upon the rectifier R. The carrier frequency is transmitted at all times, regardless of whether or not a side band is being transmitted, and the output direct current of the rectifier R will correspond in amplitude to the amplitude of the carrier. The amplitude of the carrier will in turn depend upon the transmitting conditions of the transmitting medium so that the rectified current flowing through the polar relay PR will fluctuate in amplitude as the efficiency of the transmitting medium fluctuates.

If the efficiency of the transmitting medium is decreased, the armature of the polar relay PR will be shifted to one of its contacts, say the lower contact, thereby energizing the relay 19 which completes the field and armature circuits of the motor 16 to cause the motor to rotate in one direction and adjust the potentiometer 14 to gradually increase the transmission to the detector, until a condition is reached such that the amplitude of the carrier frequency will be sufficient to produce a rectified current in the rectifier R, whose strength will be of such value as to again shift the armature of the polar relay PR to neutral position, whereupon the operation of the motor will

cease. The adjustment of the transmission of the receiving channel RL is now such that the change in transmission of the transmitting medium has been compensated for, and the low frequency voice currents detected by the detector will be of normal amplitude.

If the efficiency of the transmitting medium is increased, the unmodulated carrier component would increase in amplitude, thereby causing a greater direct current to flow through the polar relay PR and this would shift the armature to the other contact and energize the relay 18, causing the motor 16 to rotate in the opposite direction and adjust the potentiometer 14 so that the transmission efficiency to the receiving channel RL is gradually decreased. This results in a gradual decreasing of the amplitude of the carrier frequency until a point is reached where the direct current flowing through the polar relay PR will be reduced to its normal value, so that the armature of the polar relay is shifted to neutral and the motor 16 stops rotating. The voice frequency currents transmitted to the circuit 13 will now have a normal amplitude.

Instead of using the motor 16 to adjust the potentiometer on the input side of the detector D, it may be arranged to adjust a potentiometer 20 included between the detector D and the receiving amplifier RA, as shown in Fig. 2. The net result will be the same as in the case of Fig. 1, and in this case, the adjustment of the potentiometer, instead of affecting the carrier and the side band before detection, produces a change in the amplitude of the unmodulated carrier component of the detector, and of the low frequency voice signal. The change in the amplitude of the unmodulated carrier component in the detector, in response to adjustment of the potentiometer, causes the current through the relay PR to vary in amplitude until the current becomes normal, after which the adjustment ceases. The amplitude of the low frequency voice current component is adjusted by the potentiometer at the same time, so that when the final adjustment is reached, the amplitude of the voice current will be normal.

Instead of arranging the circuit so that the rectified direct current will be automatically restored to its normal value by the adjusting means, the system may be so arranged that the direct current will at all times depend in amplitude upon the amplitude of the carrier frequency, and the value of this current may be utilized to adjust the transmission efficiency of the circuit for the low frequency voice currents only. Such an arrangement is illustrated in Fig. 3. In this case, the output circuit of the rectifier R, instead of including a polarized relay PR, includes a series of marginal relays 21, 22 and 23. The contacts of these relays are arranged to control a shunt circuit 24 including resistances 25, 26 and 27 bridged across the low frequency circuit 13. When the rectified current in the output circuit of the rectified R falls below a certain minimum value, which for purposes of illustration may be taken as 3 mils, none of the relays 21, 22 and 23 is energized. If the rectified current has a value between 3 mils and say 5 mils, only the relay 21 is energized. If the rectified current has a value between 5 mils and say 7 mils, relays 21 and 22 are energized, and for a value of rectified current greater than 7 mils, all three relays will be energized.

Suppose now the transmitting efficiency of the transmitting medium is so low that the rectified carrier component flowing through the relays 21, 22 and 23 is less than 3 mils. All three relays 21, 22 and 23 will be deenergized and the shunt path 24 will be opened at the contact of the relay 21, so that the full energy of the detected voice currents will be transmitted through the low-pass filter LPF into the circuit 13. If the transmission efficiency of the medium is increased, so that the rectified carrier component attains a value of over 3 mils but less than 5 mils, relay 21 will be energized and relays 22 and 23 deenergized. Under these conditions, the bridge 24 will be closed at the contact of relay 21 and resistances 25, 26 and 27 will be included in the bridge. This will shunt a certain proportion of the energy of the low frequency voice currents into the bridge, thereby reducing the voice energy transmitted to the circuit 13 to the normal value.

If the efficiency of the transmitting medium is still further increased, so that the rectified current attains a value between 5 mils and 7 mils, relays 21 and 22 will be actuated and relay 23 will be deenergized. Relay 22 short-circuits resistance 25, so that the bridge 24 will now be closed through resistances 26 and 27 in series. Under these conditions, a still greater proportion of the voice current energy will be shunted through the bridge, so that the voice current energy transmitted to the circuit 13 will be substantially normal. If the amplitude of the carrier frequency is still further increased by an increase in efficiency of the transmitting medium, the rectified current may attain a value of 7 mils or over, in which case the relay 23 will be energized, in addition to relays 21 and 22. Both resistances 25 and 26 will now be short-circuited and the bridge circuit 24 will include only the resistance 27, thereby shunting a still greater proportion of the voice energy into the bridge and maintaining the energy transmitted to the circuit 13 substantially normal.

It will be obvious that the general princi-

ples herein disclosed may be embodied in many other organizations widely different from those illustrated, without departing from the spirit of the invention as defined in the folowing claims.

What is claimed is:

1. In a system for controlling transmission, a transmitting medium over which the carrier is transmitted together with the side band, the transmission efficiency of said medium being variable under different conditions, a receiving channel including a detector upon which the side band and carrier may be simultaneously impressed to detect the low frequency signaling currents represented by the side band, means to select from the output of the detector the unmodulated carrier frequency current, means to produce from the selected carrier component a current having characteristics depending upon the transmission conditions to which the carrier has been subjected, and a mechanical switching device operated by the current thus produced to adjust a circuit element of the receiving channel in accordance with the characteristics of the current thus produced to compensate for the change in efficiency of the transmitting medium.

2. In a system for controlling transmission, a transmitting medium over which the carrier is transmitted together with the side band, the transmission efficiency of said medium being variable under different conditions, a receiving channel including a detector upon which the side band and carrier may be simultaneously impressed to detect the low frequency signaling currents represented by the side band, means to select from the output of the detector the unmodulated carrier frequency component, means to produce from the selected carrier component a direct current whose amplitude depends upon the transmission conditions to which the carrier has been subjected, and mechanical switching means operated by the direct current for adjusting a circuit element of the receiving channel in accordance with the amplitude of said direct current to compensate for the change efficiency of the transmitting medium.

3. In a system for controlling transmission, a transmitting medium over which the carrier is transmitted along with the side band, the transmission efficiency of said medium being variable under different conditions, a receiving channel including a detector upon which the carrier and side band may be simultaneously impressed, means for selecting the carrier, means for producing from the carrier a current whose characteristics depend upon the transmission conditions to which the carrier has been subjected, a circuit element in said receiving channel, and mechanical switching means controlled in accordance with the characteristics of said current to adjust said circuit element to compensate for the change in efficiency of the transmitting medium.

4. In a system for controlling transmission, a transmitting medium over which the carrier is transmitted along with the side band, the transmission efficiency of said medium being variable under different conditions, a receiving channel upon which the carrier and side band may be impressed, means for selecting the carrier, a rectifying device to rectify the selected carrier to produce a direct current having an amplitude depending upon the transmission conditions to which the carrier has been subjected, a circuit element in said receiving channel, and mechanical switching means controlled in accordance with the amplitude of the rectified current to adjust said circuit element to compensate for the change in efficiency of the transmitting medium.

5. In a system for controlling transmission, a transmitting medium over which the carrier is transmitted along with the side band, the transmission efficiency of said medium being variable under different conditions, a receiving channel including a detector upon which the carrier and side band may be impressed, means for selecting the carrier, means for producing from the selected carrier a current whose characteristics depend upon the transmission conditions to which the carrier has been subjected, a potentiometer in said receiving channel, and means for adjusting said potentiometer in accordance with the characteristics of the current produced from the selected carrier to compensate for the change in transmission efficiency of the transmitting medium.

6. In a system for controlling transmission, a transmitting medium over which the carrier is transmitted along with the side band, the transmisson efficiency of said medium being variable under different conditions, a receiving channel including a detector upon which the carrier and side band may be impressed, means for selecting the carrier, a rectifying device to rectify the selected carrier to produce a direct current having an amplitude depending upon the transmission conditions to which the carrier has been subjected, a potentiometer in said receiving channel, and means to adjust said potentiometer in accordance with the amplitude of the rectified current to compensate for the change in efficiency of the transmitting medium.

7. In a system for controlling transmission, a transmitting medium over which the carrier is transmitted together with the side band, the transmission efficiency of said medium being variable under different conditions, a receiving channel including a detector upon which the side band may be impressed together with the carrier to detect

the low frequency signaling currents represented by the side band, means to select the unmodulated carrier component from the output of said detector, means to produce from said selected carrier component a direct current whose amplitude depends upon the transmission conditions to which the carrier has been subjected, a potentiometer in said receiving channel, and means to adjust said potentiometer in accordance with the amplitude of said direct current to compensate for the change in transmission efficiency of said transmitting medium.

In testimony whereof, I have signed my name to this specification this 3rd day of May, 1922.

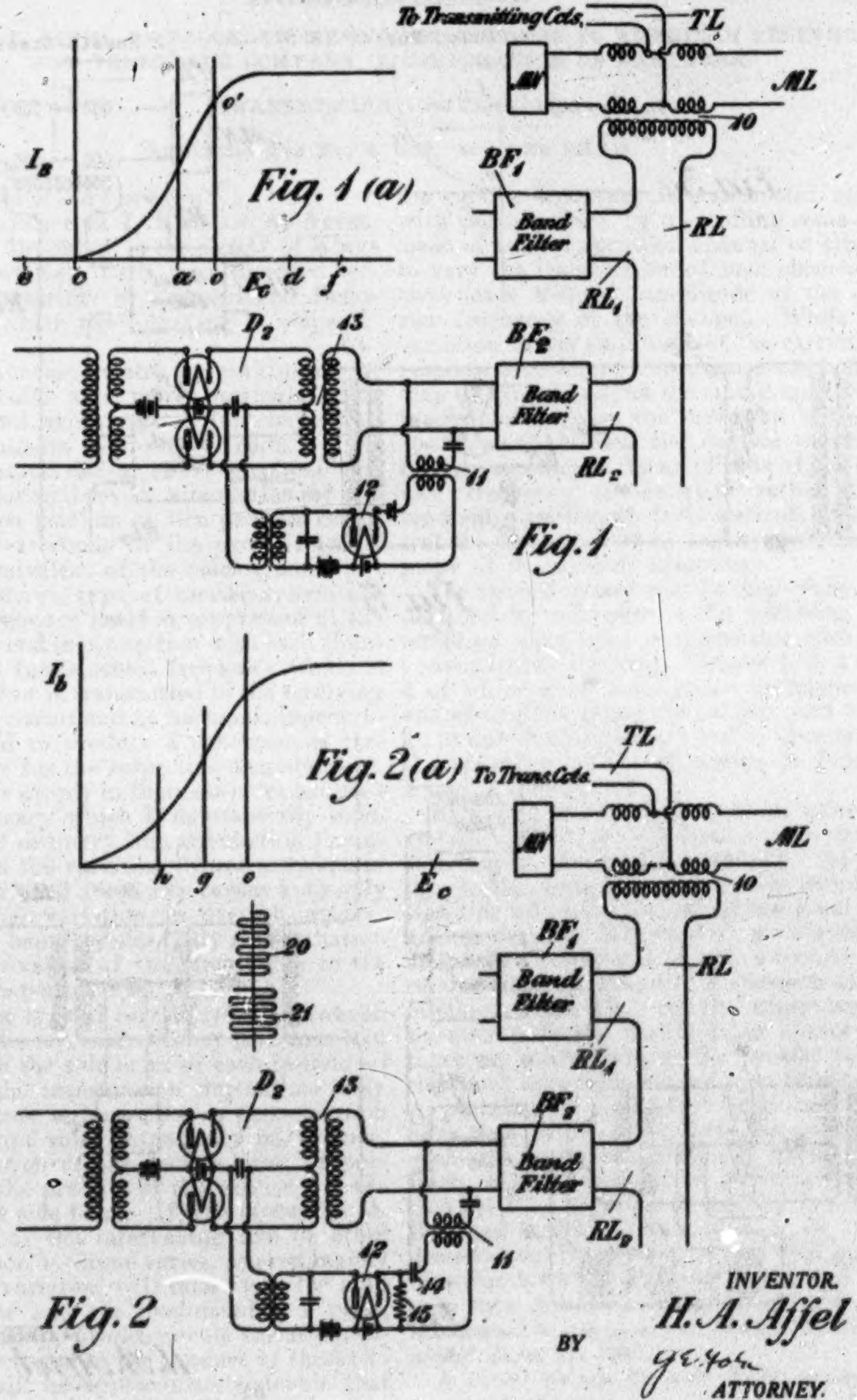
HERMAN A. AFFEL.

Oct. 7, 1924. 1,511,014

H. A. AFFEL

TRANSMISSION REGULATION

Filed May 4, 1923 2 Sheets-Sheet 1



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TRANSMISSION REGULATION

Filed May 4, 1922 2 Sheets-Sheet 2

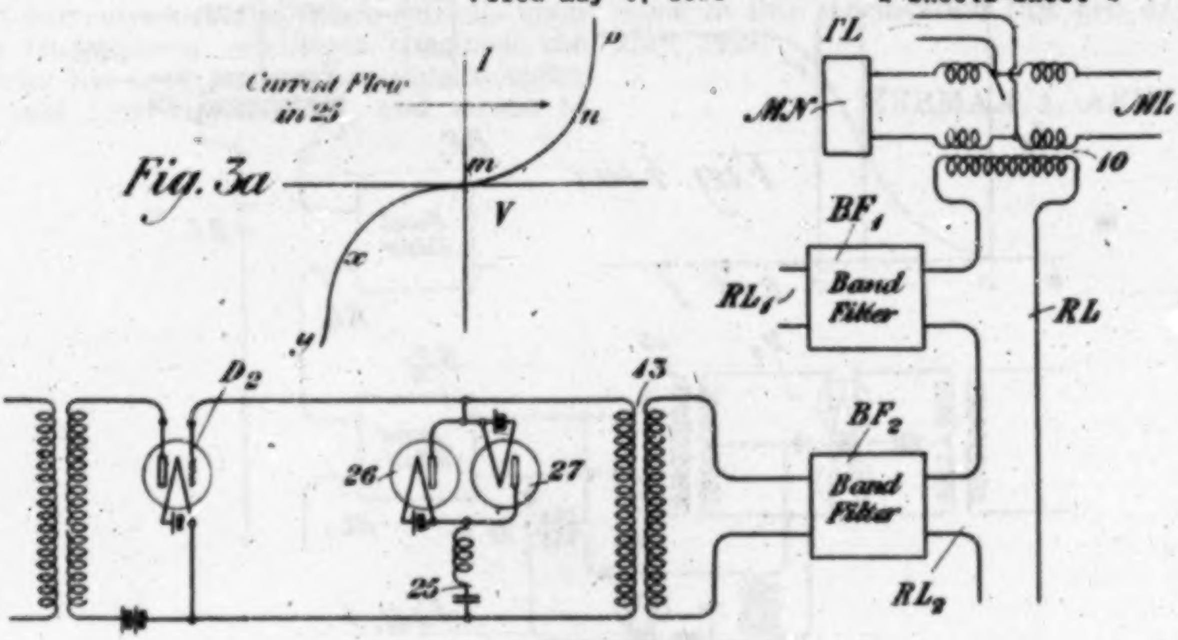

Fig. 3a

Fig. 3

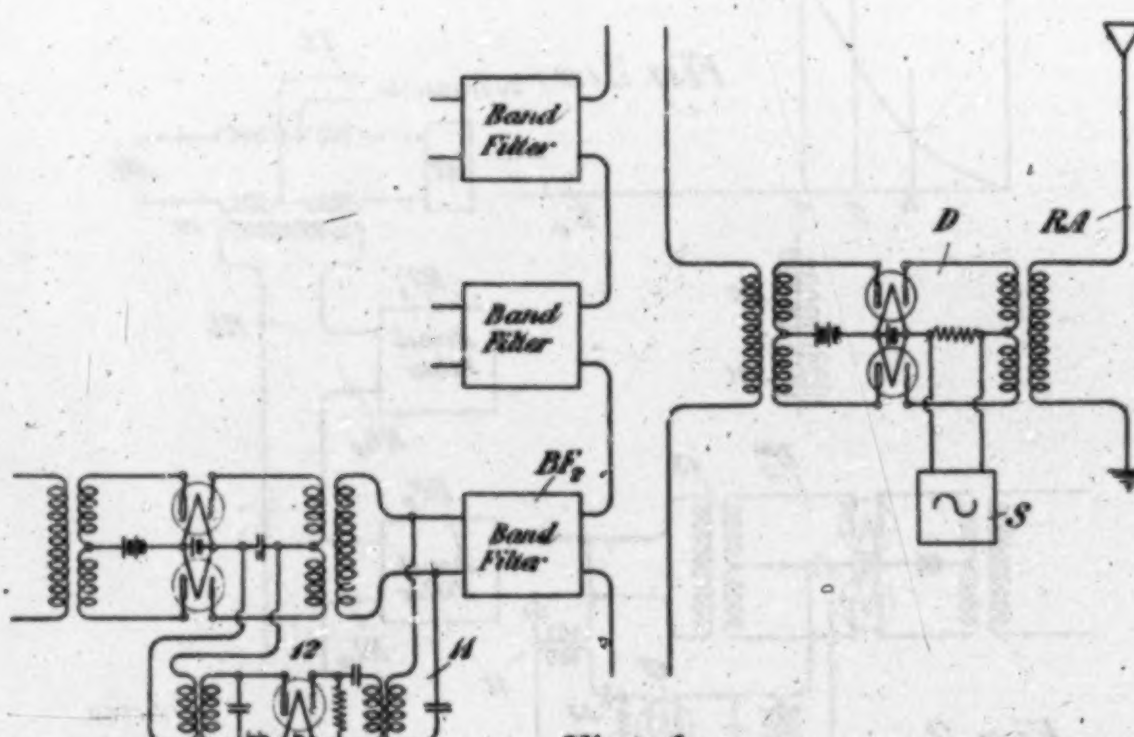

Fig. 4

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Patented Oct. 7, 1924. **1,511,014**

UNITED STATES PATENT OFFICE.

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TRANSMISSION REGULATION.

Application filed May 4, 1922. Serial No. 558,445.

To all whom it may concern:

Be it known that I, Herman A. Affel, residing at Brooklyn, in the county of Kings and State of New York, have invented certain Improvements in Transmission Regulation, of which the following is a specification.

This invention relates to multiplex signaling circuits and more particularly to methods and arrangements for controlling the transmission over such circuits.

In a wire carrier or radio telephone system the fluctuations in attenuation of the transmission medium or line produce corresponding variations in the over-all transmission equivalent of the voice circuit. In one well known type of carrier system the carrier frequency itself is suppressed at the modulator end in connection with each channel, and a fundamental frequency which is relatively low is transmitted to the receiving end of the circuit and by harmonic regeneration caused to produce a synchronous carrier supply for the respective demodulators. The carrier supply in this case is transmitted at a frequency which is substantially independent of ordinary line attenuation fluctuations, and the variation in line attenuation at the side band frequency causes a directly proportional variation in over-all equivalent, there being substantially no fluctuation of the equivalent of the circuit due to the carrier component itself.

With the type of carrier system, however, in which the carrier frequency is transmitted along with the side band of each individual channel, the transmission fluctuations may be even more serious since in demodulation the resultant voice output may be, for normal operation of the demodulator, proportional to the product of the carrier and the modulated side band. If, therefore, the attenuation of the intervening line or other transmission medium varies, approximately the same variation will take place for both the carrier and the modulated side band, and the resultant voice circuit variation, being proportional to the product of these two factors, will be approximately double that of the line attenuation itself.

In accordance with the present invention it is proposed to overcome the difficulties encountered in connection with transmission fluctuations in the type of circuit in which the carrier frequency is transmitted along with the side band, by controlling some element of the transmission channel or circuit to vary the transmission of such element in accordance with the amplitude of the carrier frequency of the channel. While the variation in the amplitude of the carrier, in response to different transmission conditions, may be made to adjust the circuit conditions in various ways, as the invention is herein specifically disclosed the control exercised by the variation in the amplitude of the carrier frequency is electrical rather than mechanical, although both methods of control are contemplated by and are within the scope of the present invention.

The invention may now be more fully understood by reference to the following description when read in connection with the accompanying drawing, Figures 1, 2, 3 and 4 of which show four circuit arrangements embodying the present invention, and Figs. 1ª, 2ª and 3ª of which are curves illustrating the operation of the apparatus in Figs. 1, 2 and 3 respectively.

Referring to Fig. 1, so much of a carrier system is shown as is necessary to an understanding of the present invention. In this figure, ML designates the carrier transmission line which is balanced by the usual balancing network MN, and is associated by means of a hybrid coil 10 with a common receiving channel RL, and a common transmitting circuit TL. As the apparatus associated with the transmitting circuit TL takes no active part in the present invention, such apparatus has not been illustrated. A plurality of individual receiving channels, such as RL_1, RL_2, etc., are connected with the common receiving circuit RL. Each receiving channel as, for example, the channel RL_2, includes a band filter such as BF_2 and a demodulator such as D_2. The demodulator D_2 may be of any well known type but is shown as being a balanced vacuum tube demodulator of the general type illustrated in the patent to Carson, 1,343,308, issued June 15, 1920.

A tuned circuit 11 is bridged across the receiving channel RL_2, this circuit being tuned to the carrier frequency and adapted to select the carrier frequency from the side band or bands transmitted therewith. The tuned circuit is associated with the input of

a vacuum tube 12 adapted to control the carrier frequency in a manner hereinafter described. The output circuit of the vacuum tube 12 is connected with the common branch of the input circuits of the demodulator D_2, so that the carrier frequency selected from the channel RL_2, is impressed upon the demodulator differentially with respect to the side bands, which are transmitted directly to the modulator. This differential or balanced connection at the detector prevents the possibility of singing at the carrier frequency over the path through the tuned circuit 11, the vacuum tube 12, the input circuit of the demodulator D_2, and the transformer 13, by which the side bands are impressed upon the demodulator.

In order to understand how the variations in transmission of the carrier frequency operate through the vacuum tube 12 to control the transmission equivalent of the circuit as a whole, reference will be had to the characteristic curve of Fig. 1ª, said characteristic curve being the usual curve plotted between the grid voltage and space current. When the grid voltage of the tube 12 is zero, the space current will have the amplitude indicated at *oo'*. When the grid is made negative by the amount indicated at *oc* the space current will be zero. As the grid is made positive the current increases to a value slightly above the value *oo'* until the point of saturation is reached. Upon reaching the point of saturation, further increase in the grid potential produces no further increase in current.

Suppose now the normal grid voltage be adjusted by means of the usual C battery, so as to be negative by the amount indicated at *oa*. If, now, we assume that an alternating current alternating from the positive value *ad* to a negative value *ac* is superposed upon the normal grid voltage, the space current will fluctuate from zero to the value indicated at the horizontal part of the characteristic curve, and an alternating current whose amplitude is represented by the distance between the flat part of the curve and the base line will result. If the amplitude of the alternating potential is increased so that it alternates between *e* and *f*, for example, the fluctuation in current in the output circuit will be the same as before, and the resultant alternating current in the outgoing circuit will not be increased in amplitude, notwithstanding the increase in amplitude of the voltage applied to the input circuit.

If then, the saturation point of the tube 12 be set sufficiently low so that the alternating potential of smallest amplitude resulting from the transmission of the carrier frequency will produce an output current fluctuating between zero and the point of saturation, any increase in the amplitude of the carrier selected by the tuned circuit 11 will merely result in the transmission of the carrier frequency to the common branch of the demodulator D_2, whose amplitude will be the same as before. In short, notwithstanding that the amplitude of the carrier frequency may be increased or decreased from time to time as it is received from the main line ML, the carrier frequency supplied to the demodulator D_2 will be constant in amplitude so long as the amplitude of the carrier received from the line ML is not less than that indicated by the limits *cd*.

It will be seen therefore that however the transmission over the line ML may vary, the carrier frequency supplied to the demodulator D_2 will be constant if the variation is kept within certain limits, and the detected talking current will only change in volume with the change in transmission of the side band. The variation in the transmission of the carrier will produce no additional variation in the volume of the low frequency talking currents.

Fig. 2 shows an arrangement in which the system will compensate for the variation in transmission of both the side band and the carrier. Referring to Fig. 2, the tube 12 has a blocking condenser included in its input circuit and a leak resistance 15 is connected between the grid and the filament. Otherwise, the circuit is similar to that illustrated in Fig. 1. The constants of the tube 12 are so adjusted that the point of saturation will not be reached by the alternating potentials applied to the tube, and for an alternating potential of any amplitude occurring in practice the tube will only be working over a relatively small portion of its characteristic, instead of over the major portion of its characteristics, as described in connection with Fig. 1.

Referring now to Fig. 2ª, which illustrates the characteristic curve of the tube 12 of Fig. 2, let us assume that normally no potential is applied to the grid. If an alternating potential is then applied to the grid circuit as indicated by the curve 20, the successive negative waves will be trapped by the blocking condenser 14 to produce an accumulated charge upon the grid which will leak off at some definite rate through the resistance 15. By properly adjusting the resistance 15 a steady state will soon be reached at which the accumulated charge upon the grid will have the value indicated by *og*. When this condition is reached the alternating potential 20 may be considered as alternating about the point *g* instead of the point *o* so that for an alternating potential having an amplitude indicated at 20, the tube 12 will be operating upon the amplifying portion of its characteristic at the point of greatest amplification.

If now, the alternating potential applied

to the grid be increased in amplitude, as indicated at 21, the charge which builds up upon the grid will become greater when the steady state is reached so that the average negative charge on the grid may be considered to have the value represented by *oh*. The alternating potential will now fluctuate about the point *h* instead of about the point *g*, so that the tube will be operating at a part of its characteristic which produces a smaller amplification than was produced at the point *g*. The resultant alternating current in the output circuit of the tube will therefore be smaller in amplitude for an alternating potential, as indicated at 21, than it will be for the alternating potential of smaller amplitude indicated at 20. In other words, the tube 12 will operate to decrease the output alternating current of carrier frequency as the input alternating current of carrier frequency increases in amplitude. By properly adjusting the characteristic of the tube, this decrease in amplitude of the carrier applied to the demodulator D_2 as the amplitude of the carrier transmitted over the line ML increases, may be made to compensate for the increase in the amplitude of the side band with the result that the detected voice currents, which are proportional to the product of the carrier and the side band applied to the demodulator, will have substantially the same volume regardless of changes in the transmission equivalent of the line ML.

A modified arrangement obtaining substantially the same result is illustrated in Fig. 3. In the arrangement shown in Fig. 3, the demodulator D_2 may be a simple vacuum tube demodulator instead of a duplex arrangement such as that illustrated in Figs. 1 and 2. Across the input circuit of the demodulator a circuit 25, tuned to the carrier frequency, may be bridged, and in this circuit is included a pair of two-element vacuum tubes 26 and 27, of the rectifying type. One of these tubes will transmit one-half of the alternating carrier wave and the other tube will transmit the other half of the alternating carrier wave. The impedance of these tubes will be decreased as the amplitude of the carrier frequency increases, so that the amount of energy of the carrier frequency which is by-passed through the tuned circuit 25 will increase with the amplitude of the carrier frequency.

This action may be understood by referring to the curve of Fig. 3[a], which illustrates the characteristic of the shunt circuit 25. In Fig. 3[a] the portion of the curve *mnp* may be considered to correspond to the voltage-current curve of one of the tubes 26 or 27, while the portion of the curve *mxy* may be considered the corresponding characteristic curve of the other tube. The characteristics of these tubes are such that as the applied voltage increases the current increases more rapidly than the voltage, provided the voltage is kept somewhat below saturation.

If, therefore, an alternating current of zero amplitude is impressed upon the circuit 25, the circuit will have an infinite impedance and zero current will flow. If the amplitude of the applied alternating potential be increased the impedance of the circuit will be decreased and the impedance continually decreases with increase in amplitude. By operating with alternating potentials between maximum and minimum limits the current will increase with the increase in the applied voltage at such a rate that the shunt circuit 25 will compensate for the variations in transmission over the line ML. For example, for a given transmission equivalent of the circuit ML a definite proportion of the energy of the carrier frequency will be by-passed through the circuit 25 and the carrier energy applied to the demodulator D_2 will have a certain amplitude while the side band will be impressed upon the demodulator without having any of its energy diverted over the path 25. If, now, the transmission equivalent of the circuit ML is changed so that the amplitude of both the carrier and the side band are decreased without being transmitted over said circuit, a smaller proportion of the carrier frequency energy will be by-passed by the shunt circuit 25, and the actual amount of energy of the carrier frequency impressed upon the demodulator may be increased over that before impressed thereon. This increase, by proper adjustment, may be made sufficient to compensate for the decreased amplitude of the side band impressed upon the demodulator, so that the resultant detected voice currents will have the same volume, these currents being produced by the product of the carrier frequency and side band.

In some cases, and particularly in radio transmission, it would be difficult to select the carrier frequency from the modulated side band, owing to the fact that the frequencies involved are relatively high, and the selectivity, particularly that provided by simple tuned circuits, is low. In such a case it is desirable that an arrangement similar to that shown in Fig. 4 be utilized. In this circuit the energy incoming from the receiving antenna RA is impressed upon an intermediate demodulator D so that the incoming energy beats with a frequency from the source S to step down the received carrier and side band in the frequency spectrum. The stepped down carrier frequency and side band may then be passed together through the band filter BF_2 and a carrier selected from the side band by means of the tuned circuit 11, as in the case of Figs. 1 and 2. The tube 12 may function as described in connection with Fig. 2, to maintain the

volume of the detected voice currents substantially constant regardless of changes in the attenuation of the original frequencies during transmission.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated without departing from the spirit of the invention as defined in the appended claims.

What is claimed is:

1. The method of controlling transmission in a carrier system in which the carrier is transmitted along with the side band, which consists in transmitting components corresponding to the carrier and side band over a medium whose transmission is variable under different conditions, selecting a component corresponding to the carrier from the corresponding side band component, producing from the selected component a current having characteristics depending upon the transmission conditions to which the transmitted energy has been subjected, and controlling the amplitude of the low frequency signaling currents produced from the transmitted side band component in accordance with the characteristics of the current produced from the component corresponding to the carrier.

2. The method of controlling transmission in a carrier system in which the carrier is transmitted along with the side band, which consists in transmitting components corresponding to the carrier and side band over a medium whose transmission is variable under different conditions, selecting a component corresponding to the carrier from the corresponding side band component, producing from the selected component a current whose amplitude depends upon the transmission conditions to which the transmitted energy has been subjected, and controlling the amplitude of the low frequency signaling currents produced from the transmitted side band component in accordance with the amplitude of the current produced from the component corresponding to the carrier.

3. The method of controlling transmission in a carrier system in which the carrier is transmitted along with the side band, which consists in transmitting components corresponding to the carrier and side band over a medium whose transmission is variable under different conditions, selecting a component corresponding to the carrier from the corresponding side band component, translating the selected component into a current of greater amplitude if the amplitude of the component corresponding to the carrier after transmission is less than the average, and translating the selected component into a current of lesser amplitude if the component corresponding to the carrier after transmission is greater than the average, and combining the translated component and a component corresponding to the side band, to produce detected signals whose amplitude depends on the translated component and said component corresponding to the side band.

4. The method of controlling transmission in a carrier system in which the carrier is transmitted along with the side band, which consists in transmitting components corresponding to the carrier and side band over a medium whose transmission is variable under different conditions, producing a change in the amplitude of a received component corresponding to the carrier before detection, said change being determined by the amount by which the amplitude of the received component varies from the average, and combining the component as thus changed in amplitude with a component corresponding to the received side band to produce a signaling current.

5. The method of controlling transmission in a carrier system in which the carrier is transmitted along with the side band, which consists in transmitting components corresponding to the carrier and side band over a medium whose transmission is variable under different conditions, changing the amplitude of a component corresponding to the carrier after transmission and before detection by an amount depending upon the transmission conditions to which the carrier has been subjected, and then combining the component thus changed in amplitude with a component corresponding to the side band, to produce a signaling current.

6. In a system for controlling transmission, a transmitting medium over which a carrier is transmitted together with the side band, the transmission efficiency of said medium being variable under different conditions, means for selecting a component corresponding to the carrier from a component corresponding to the side band after transmission, means to produce from the selected component a current having characteristics depending upon the transmission conditions to which the carrier has been subjected, means to produce low frequency signaling current from the side band, and means to control the amplitude of the low frequency signaling currents produced from the side band in accordance with the characteristics of the current produced from the selected component.

7. In a system for controlling transmission, a transmitting medium over which a carrier is transmitted together with the side band, the transmission efficiency of said medium being variable under different conditions, means for selecting a component corresponding to the carrier from a component corresponding to the side band after transmission, means to produce from the selected component a current whose amplitude de-

pends upon the transmission conditions to which the carrier has been subjected, means to produce low frequency signaling current from the side band, and means to control the amplitude of the low frequency signaling currents produced from the side band in accordance with the amplitude of the current produced from the selected component.

8. In a system for controlling transmission, a transmitting medium over which a carrier is transmitted together with a side band, the transmission efficiency of said medium being variable under different conditions, means to select a component corresponding to the carrier from a component corresponding to the side band, a translating device upon which the selected component may be impressed, said translating device being so arranged as to increase the amplitude of the component if it is less than the average and to decrease the amplitude of the component if it is greater than the average, a demodulator, and means to impress the component thus translated in amplitude upon said demodulator together with a component corresponding to the side band, thereby producing a low frequency signaling current whose amplitude will depend upon the translated component and received side band.

9. In a system for controlling transmission, a transmitting medium over which a carrier is transmitted together with the side band, the transmission efficiency of said medium being variable under different conditions, means to select a component corresponding to the carrier from a component corresponding to the side band, a vacuum tube upon which the selected component may be impressed, said vacuum tube having a characteristic such that when the amplitude of the component is greater than the average the component frequency in the output circuit will be decreased in amplitude and when the amplitude of the component is less than the average the amplitude of the component frequency appearing in the output circuit will be increased, a detector, and means to impress the frequency appearing in the output circuit of said vacuum tube upon said detector together with a component corresponding to the side band, thereby producing a detected signaling current whose amplitude is determined by the frequency appearing in the output circuit of the vacuum tube and by the side band.

10. In a system for controlling transmission, a transmitting medium over which the carrier may be transmitted along with the side band, the transmission efficiency of said medium being variable under different conditions, a detector upon which components corresponding to the carrier and side band may be impressed, and means for subjecting the component corresponding to the carrier to a change in amplitude before impressing it upon the detector, said change being determined by the attenuation to which it is subjected by the transmission medium.

11. In a system for controlling transmission, a transmitting medium over which the carrier may be transmitted along with the side band, the transmission efficiency of said medium being variable under different conditions, a detector upon which components corresponding to the carrier and the side band may be impressed, and means for changing the amplitude of the component corresponding to the carrier before impressing it upon the detector, the change in amplitude being inverse with respect to its variation from the average amplitude resulting from transmission over said transmission medium.

In testimony whereof I have signed my name to this specification this 3rd day of May, 1922.

HERMAN A. AFFEL.

Oct. 7, 1924. **1,511,015**

H. A. AFFEL

TRANSMISSION REGULATION

Filed May 4, 1922

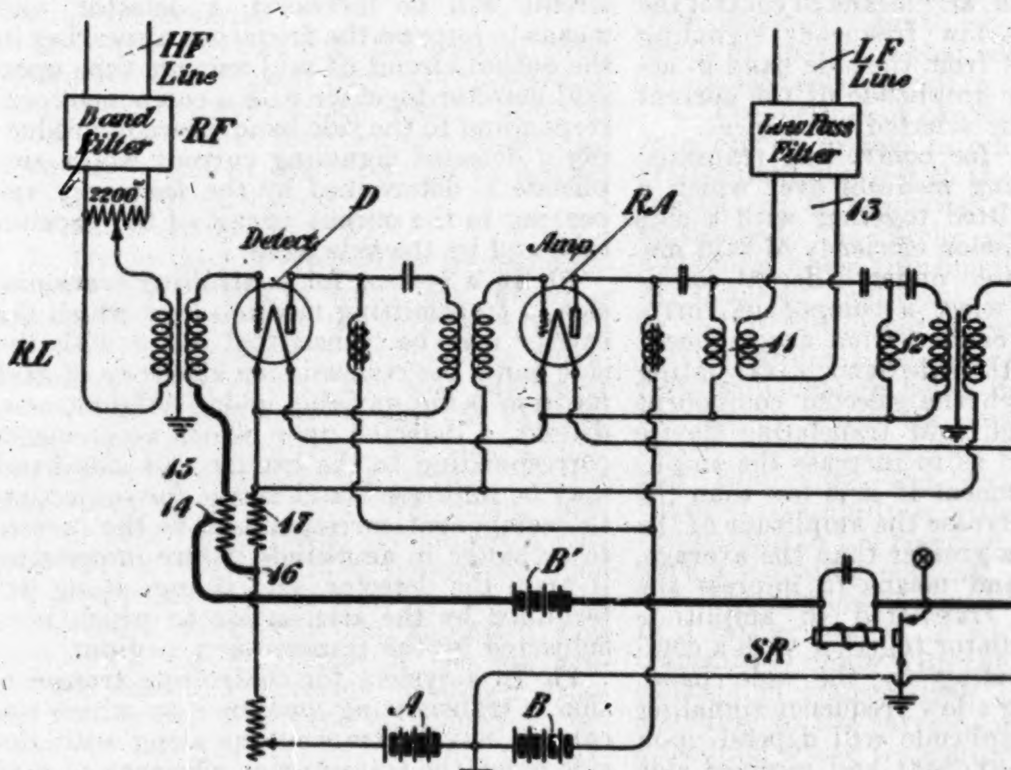

Fig. 1

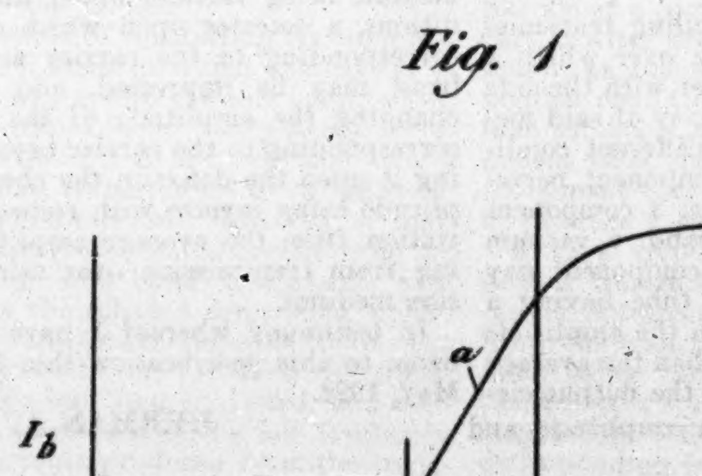

Fig. 2

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Patented Oct. 7, 1924. 1,511,015

UNITED STATES PATENT OFFICE.

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TRANSMISSION REGULATION.

Application filed May 4, 1922. Serial No. 558,446.

To all whom it may concern:

Be it known that I, Herman A. Affel, residing at Brooklyn, in the county of Kings and State of New York, have invented certain Improvements in Transmission Regulations, of which the following is a specification.

This invention relates to multiplex signaling circuits, and more particularly to methods and arrangements for controlling the transmission over such circuits.

In a wire carrier or radio telephone system, the fluctuations in attenuation of the transmission medium or line produce corresponding variations in the over-all transmission equivalent of the voice circuit. In one well known type of carrier system, the carrier frequency itself is suppressed at the modulator end in connection with each channel, and the fundamental frequency, which is relatively low, is transmitted to the receiving end of the circuit, and by harmonic regeneration, caused to produce a synchronous carrier supply for the respective demodulators. The carrier supply in this case is transmitted at a frequency which is substantially independent of ordinary line attenuation fluctuations and the variation in line attenuation at the side band frequency causes a directly proportional variation in the over-all equivalent, there being substantially no fluctuation of the equivalent of the circuit due to the carrier component itself.

With the type of carrier system, however, in which a carrier frequency is transmitted along with the side band of each individual channel, the transmission fluctuations may be even more serious, since in demodulation the resultant voice output may, for normal operation of the demodulator, be proportional to the product of the carrier and the modulated side band. If, therefore, the attenuation of the intervening line or other transmission medium varies, approximately the same variation will take place for both the carrier and the modulated side band, and the resultant voice circuit variation, being proportional to the product of these two factors, will be approximately double that of the line attenuation itself.

In accordance with the present invention, it is proposed to overcome the difficulties encountered in connection with transmission fluctuations in the type of circuit in which the carrier frequency is transmitted along with the side band, by controlling some element of the transmission channel or circuit to vary the transmission of such element in accordance with the amplitude of the carrier frequency of the channel. Preferably, the control thus exercised will be applied to an element in the receiving channel at a receiving station by selecting the carrier frequency component, rectifying the selected component to produce a direct current whose amplitude will depend on the transmission conditions to which the carrier has been subjected, and controlling the transmission element by the rectified current. The control exercised by the rectified current may be effected either electrically or mechanically, but in the preferred form herein disclosed, an electrical system of control is illustrated.

The invention may now be more fully understood by reference to the following description, when read in connection with the accompanying drawing, Figure 1 of which shows a circuit diagram embodying the principles of the invention, and Fig. 2 is a curve illustrating the operation of one of the vacuum tube circuits shown in Fig. 1.

Referring to Fig. 1, so much of the carrier system is shown as is necessary to an understanding of the present invention. In this figure, RL designates the receiving channel of one transmission circuit of a carrier telegraph system, said channel being connected, together with other similar channels (not shown), to a common transmission line (not shown), over which carrier frequencies are transmitted. The corresponding transmitting channel is not illustrated, as it is not involved in the present invention. The receiving channel RL includes a band filter RF for selecting the desired side band and the corresponding carrier, a detector D and a receiving amplifier RA. The detector D may be of any well known type, such as a vacuum tube detector, and is adapted to detect the voice currents corresponding to the side band by beating the side band with the carrier. The receiving amplifier RA may be any well known type of amplifier, but is illustrated as being a vacuum tube amplifier and is arranged to amplify the detected voice currents as well as the unmodulated carrier component appearing in the output circuit of the detector. The output circuit of the receiving am-

plifier RA includes a transformer 11 by which the low frequency circuit 13 (which may be associated with a low frequency transmission line) is connected to the receiving channel.

The circuit 13 includes a low-pass filter by which the voice frequency currents are selected into said circuit to the exclusion of the higher frequency components, such as the unmodulated carrier. The carrier frequency component may be selected by means of a tuned circuit or filter 12 through which the carrier frequency is impressed upon a rectifier R. The rectifier R may be of any well known type but is illustrated as a vacuum tube arrangement adapted to translate the selected carrier component into a direct current. In systems of this type, this direct current is primarily used to control the operation of a signal relay SR, which is illustrated as being included in the output circuit of the rectifier. This signal relay is adapted to operate a ringing signal when the carrier is interrupted at the sending station, the interruption of the carrier (which is normally transmitted) resulting in the cessation of the flow of direct current in the output circuit of the rectifier.

In the present invention, this circuit is also utilized to control the transmission efficiency of the detector D, and for this purpose the output circuit of the rectifier may be traced from ground to the filament of the rectifier, through the space in the tube to the plate of the rectifier and then through the winding of the relay SR, battery B′ to point 14 of resistance 15, thence to junction point 16 of resistances 15 and 17, through the resistance 17 and through the series connected filaments of the detector D, amplifier RA and rectifier R to ground. A connection also extends from the point 14, through the upper half of resistance 15 to the grid of the detector D. It will be seen, therefore, that the potential of the grid D is made to depend upon the amplitude of the rectified current flowing in the plate circuit of the rectifier R.

Disregarding for the moment the connection of this plate circuit to the grid of the detector D through the point 14, it will be seen that the grid of the detector D may be made normally negative with respect to the filament, by reason of the fact that the battery A, which supplies the filament heating current through the resistance 17, is connected to the grid of the detector D through the resistance 15, and by properly proportioning the resistance 15 with respect to the resistance 17, the grid may be made more negative than the filament. The connection of the plate circuit of the rectifier R to the point 14, however, results in superposing a negative potential (depending upon the value of the rectified current) upon the grid of the detector D, in addition to the negative potential supplied from the battery A. Under normal transmission conditions, the rectified current flowing in the plate circuit of the rectifier R will have a definite negative potential, so that the resultant potential upon the grid of the detector D may be made to correspond to the point *y* of the characteristic curve *a* of Fig. 2, this curve representing the variation in the plate current of the detector with variation in the grid potential of the detector.

The point *x* of the characteristic curve may be taken as the point at which the greatest curvature occurs, and consequently, the detector will be most efficient at this point. The point *s* of the characteristic curve is a point at which the curvature is much less than at the point *x*, and this may be considered the point at which the detector will be least efficient over its practical operating range. The point *y* is chosen at an intermediate point between the points *x* and *s*, so that under average transmission conditions, the detector will be working at the point *y*. Consequently, if the transmission efficiency of the carrier circuit or medium is decreased, so that the amplitude of the carrier current is decreased, the rectified direct current flowing in the output circuit of the rectifier R will be correspondingly decreased and the grid of the detector will become more positive, so that the operating point of the detector will be shifted toward the point *x*, thereby increasing the efficiency of the detector. This increased efficiency will obviously manifest itself not only in an increased detection efficiency, but since the operation is now taking place on a portion of the characteristic curve which has greater slope, it will also manifest itself in greater amplification for the currents which pass through the tube substantially undistorted, such as the carrier current itself. By a proper adjustment, this increase in efficiency may be made to compensate for the decreased amplitude of the carrier and side band, so that the resultant detected voice currents will be the same as under average conditions.

Likewise, if the efficiency of the transmission medium be increased above the average condition, the amplitude of the carrier current will be increased, with a corresponding increase in the amplitude of the direct current flowing in the output circuit of the rectifier R. Consequently, the grid of the detector D will be made more negative than before, and its operating point will be shifted toward *s* with a corresponding decrease in the operating efficiency of the detector. This decrease may be so regulated in any given case as to compensate for the increased amplitude of the

carrier and side band, with the result that the detected voice frequency will be substantially no greater than under the average condition. It will be evident that the effective amplification of the detector will also be decreased because the operation will take place over a portion of the characteristic curve which is less steep.

In this manner, the change in transmission conditions in the carrier circuit may be automatically compensated for electrically and this compensation automatically takes place regardless of whether the circuit is being used for signaling purposes or not. In other words, the carrier current being transmitted at all times regardless of whether or not there is an accompanying side band, and the control of the efficiency of the detector depending upon the amplitude of the carrier frequency, the regulation of transmission will take place whether or not the side band is transmitted.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated, without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. The method of controlling transmission in a carrier system in which the carrier is transmitted along with the side band and in which a detector is employed to detect the signal, which consists in transmitting the carrier and side band over a medium whose transmission is variable under different conditions, combining the carrier together with the side band in the detector to detect the low frequency signaling wave represented by the side band, selecting the unmodulated carrier from the output current of the detector, producing from the selected carrier a current having characteristics depending upon the transmission conditions to which the carrier has been subjected, and controlling the efficiency of the detector in accordance with the characteristics of the current thus produced to compensate for the change in efficiency of the transmitting medium.

2. The method of controlling transmission in a carrier system in which the carrier is transmitted along with the side band and in which a detector is employed to detect the signal, which consists in transmitting the carrier and side band over a medium whose transmission is variable under different conditions, combining the carrier together with the side band in the detector to detect the low frequency signaling wave represented by the side band, selecting the unmodulated carrier from the output current of the detector, producing from the selected carrier a direct current whose amplitude depends upon the transmission conditions to which the carrier has been subjected, and controlling the efficiency of the detector in accordance with the amplitude of the direct current thus produced to compensate for the change in efficiency of the transmitting medium.

3. The method of controlling transmission in a carrier system in which the carrier is transmitted along with the side band, which consists in transmitting the carrier and side band over a medium whose transmission is variable under different conditions, combining the carrier and side band in a receiving channel, selecting the carrier, producing from the selected carrier a current whose characteristics depend upon the transmission conditions to which the carrier has been subjected, and controlling the electrical characteristics of a transmission element of the receiving channel by means of the current thus produced to compensate for the change in efficiency of the transmitting medium.

4. The method of controlling transmission in a carrier system in which the carrier is transmitted along with the side band, which consists in transmitting the carrier and side band over a medium whose transmission is variable under different conditions, combining the carrier and side band in a receiving channel, selecting the carrier, rectifying the selected carrier to produce a direct current whose amplitude depends upon the transmission conditions to which the carrier has been subjected, and controlling the electrical characteristics of a circuit element of the receiving channel by means of the rectified carrier current to compensate for the change in efficiency of the transmitting medium.

5. The method of controlling transmission in a carrier system in which the carrier is transmitted along with the side band and in which the receiving channel includes a detector for detecting the signal, which consists in transmitting the carrier and side band over a medium whose transmission is variable under different conditions, combining the carrier and side band in the detector of the receiving channel, selecting the carrier, producing from the selected carrier a current whose characteristics depend upon the transmission conditions to which the carrier has been subjected, and controlling the efficiency of the detector in the receiving channel by means of the current thus produced to compensate for the change in efficiency of the transmitting medium.

6. The method of controlling transmission in a carrier system in which the carrier is transmitted along with the side band and in which the receiving channel includes a detector, which consists in transmitting the carrier and side band over a medium

whose transmission is variable under different conditions, combining the carrier and side band in the detector of the receiving channel, selecting the carrier, rectifying the selected carrier to produce a direct current whose amplitude depends upon the transmission conditions to which the carrier has been subjected, and controlling the efficiency of the detector in the receiving channel by means of the rectified carrier current to compensate for the change in efficiency of the transmitting medium.

7. The method of controlling transmission in a carrier system in which the carrier is transmitted along with the side band and in which the receiving channel includes a detector for detecting the signal, which consists in transmitting the carrier and side band over a medium whose transmission is variable under different conditions, combining the carrier together with the side band in the detector to produce low frequency signaling currents represented by the side band, selecting the unmodulated carrier component from the output current of the detector, producing from the selected carrier component a direct current whose amplitude varies in accordance with the transmission conditions to which the carrier has been subjected, and controlling the efficiency of the detector in accordance with the amplitude of said direct current to compensate for changes in the efficiency of the transmitting medium.

8. The method of controlling transmission in a carrier system in which the carrier is transmitted along with the side band and in which a vacuum tube detector having a controlling grid is employed to detect the signal, which consists in transmitting the carrier and side band over a medium whose transmission is variable under different conditions, combining the carrier together with the side band in the detector to produce low frequency signaling currents represented by the side band, selecting the unmodulated carrier component from the output current of the detector, rectifying the selected carrier component to produce a direct current whose amplitude varies in accordance with the transmission conditions to which the carrier has been subjected, and controlling the normal potential of the grid of the detector by said direct current to change its operating characteristics to compensate for changes in the efficiency of the transmitting medium.

9. In a system for controlling transmission, a transmitting medium over which the carrier is transmitted together with the side band, the transmission efficiency of said medium being variable under different conditions, a receiving channel including a detector upon which the side band and carrier may be simultaneously impressed to detect the low frequency signaling currents represented by the side band, means to select from the output of the detector the unmodulated carrier frequency component, means to produce from the selected carrier component a current having characteristics depending upon the transmission conditions to which the carrier has been subjected, and means whereby a circuit element of said receiving channel may be controlled in accordance with the charactertistics of the current thus produced to compensate for the change in efficiency of the transmitting medium.

10. In a system for controlling transmission, a transmitting medium over which the carrier is transmitted together with the side band, the transmission efficiency of said medium being variable under different conditions, a receiving channel including a detector upon which the side band and carrier may be simultaneously impressed to detect the low frequency signaling currents represented by the side band, means to select from the output of the detector the unmodulated carrier frequency component, means to produce from the selected carrier component a direct current whose amplitude depends upon the transmission conditions to which the carrier has been subjected, and means whereby a circuit element of the receiving channel may be controlled in accordance with the amplitude of said direct current to compensate for the change in efficiency of the transmitting medium.

11. In a system for controlling transmission, a transmitting medium over which the carrier is transmitted along with the side band, the transmission efficiency of said medium being variable under different conditions, a receiving channel including a detector upon which the carrier and side band may be simultaneously impressed, means for selecting the carrier, means for producing from the carrier a current whose characteristics depend upon the transmission conditions to which the carrier has been subjected, a circuit element in said receiving channel, and means for controlling said element in accordance with the charactertistics of said current to compensate for the change in efficiency of the transmitting medium.

12. In a system for controlling transmission, a transmitting medium over which the carrier is transmitted along with the side band, the transmission efficiency of said medium being variable under different conditions, a receiving channel upon which the carrier and side band may be impressed, means for selecting the carrier, a rectifying device to rectify the selected carrier to produce a direct current having an amplitude depending upon the transmission conditions to which the carrier has been subjected, a circuit element in said receiving channel,

and means for controlling said element in accordance with the amplitude of the rectified current to compensate for the change in efficiency of the transmitting medium.

13. In a system for controlling transmission, a transmitting medium over which the carrier is transmitted along with the side band, the transmission efficiency of said medium being variable under different conditions, a receiving channel including a detector upon which the carrier and side band may be impressed, means for selecting the carrier, means for producing from the selected carrier a current whose characteristics depend upon the transmission conditions to which the carrier has been subjected, and means for controlling the efficiency of said detector in accordance with the characteristics of the current thus produced to compensate for the change in transmission efficiency of the transmitting medium.

14. In a system for controlling transmission, a transmitting medium over which the carrier is transmitted along with the side band, the transmission efficiency of said medium being variable under different conditions, a receiving channel including a detector upon which the carrier and side band may be impressed, means for selecting the carrier, a rectifying device to rectify the selected carrier to produce a direct current having an amplitude depending upon the transmission conditions to which the carrier has been subjected, and means to control the efficiency of said detector in accordance with the amplitude of the rectified current to compensate for the change in efficiency of the transmitting medium.

15. In a system for controlling transmission, a transmitting medium over which the carrier is transmitted together with the side band, the transmission efficiency of said medium being variable under different conditions, a receiving channel including a detector upon which the side band may be impressed together with the carrier to detect the low frequency signaling currents represented by the side band, means to select the unmodulated carrier component from the output of said detector, means to produce from said selected carrier component a direct current whose amplitude depends upon the transmission conditions to which the carrier has been subjected, and means to control the efficiency of said detector in accordance with the amplitude of said direct current to compensate for the change in transmission efficiency of said transmitting medium.

16. In a system for controlling transmission, a transmitting medium over which the carrier is transmitted together with the side band, the transmission efficiency of said medium being variable under different conditions, a receiving channel including a detector upon which said side band may be impressed together with the carrier to detect the low frequency signaling currents represented by the side band, means to select the unmodulated carrier component from the output of said detector, means to produce from said selected carrier component a direct current whose amplitude depends upon the transmission conditions to which the carrier has been subjected, and means to control the normal potential of the grid of said detector by said direct current to compensate for the change in transmission efficiency of said transmitting medium.

17. The method of controlling transmission in a carrier system in which the carrier is transmitted along with the side band and in which an amplifier is employed at the receiving station, which consists in transmitting the carrier and side band over a medium whose transmission is variable under different conditions, combining the carrier with the side band to produce a low frequency signaling wave represented by the side band, selecting the unmodulated carrier, producing from the selected carrier a current having characteristics depending upon the transmission conditions to which the carrier has been subjected, and controlling the efficiency of the amplifier in accordance with the characteristics of the current thus produced to compensate for the change in efficiency of the transmitting medium.

18. The method of controlling transmission in a carrier system in which the carrier is transmitted along with the side band and in which a vacuum tube amplifier having a controlling grid is employed at the receiving station, which consists in transmitting the carrier and side band over a medium whose transmission is variable under different conditions, combining the carrier with the side band to produce low frequency signaling currents represented by the side band, selecting the unmodulated carrier component, rectifying the selected carrier component to produce a direct current whose amplitude varies in accordance with the transmission conditions to which the carrier has been subjected, and controlling the normal potential of the grid of the amplifier by said direct current to change its operating characteristics to compensate for the changes in the efficiency of the transmitting medium.

19. In a system for controlling transmission, a transmitting medium over which the carrier is transmitted together with the side band, the transmission efficiency of said medium being variable under different conditions, a receiving channel including an amplifier, means to combine the side band with the carrier to produce low frequency signaling currents represented by the side band, means to select the unmodulated carrier frequency component, means to produce from the selected carrier component a current hav-

ing characteristics depending upon the transmission conditions to which the carrier has been subjected, and means whereby the efficiency of said amplifier may be controlled in accordance with the characteristics of the currents thus produced to compensate for the change in efficiency of the transmitting medium.

20. In a system for controlling transmission, a transmitting medium over which the carrier is transmitted together with the side band, the transmission efficiency of said medium being variable under different conditions, a receiving channel including a vacuum tube amplifier, means in said channel to combine the carrier with the side band to produce low frequency signaling currents represented by the side band, means to select the unmodulated carrier component, means to produce from said selected carrier component a direct current whose amplitude depends upon the transmission conditions to which the carrier has been subjected, and means to control the normal potential of the grid of the amplifier by said direct current to compensate for the changes in the effiency of the transmitting medium.

In testimony whereof, I have signed my name to this specification this 3rd day of May, 1922.

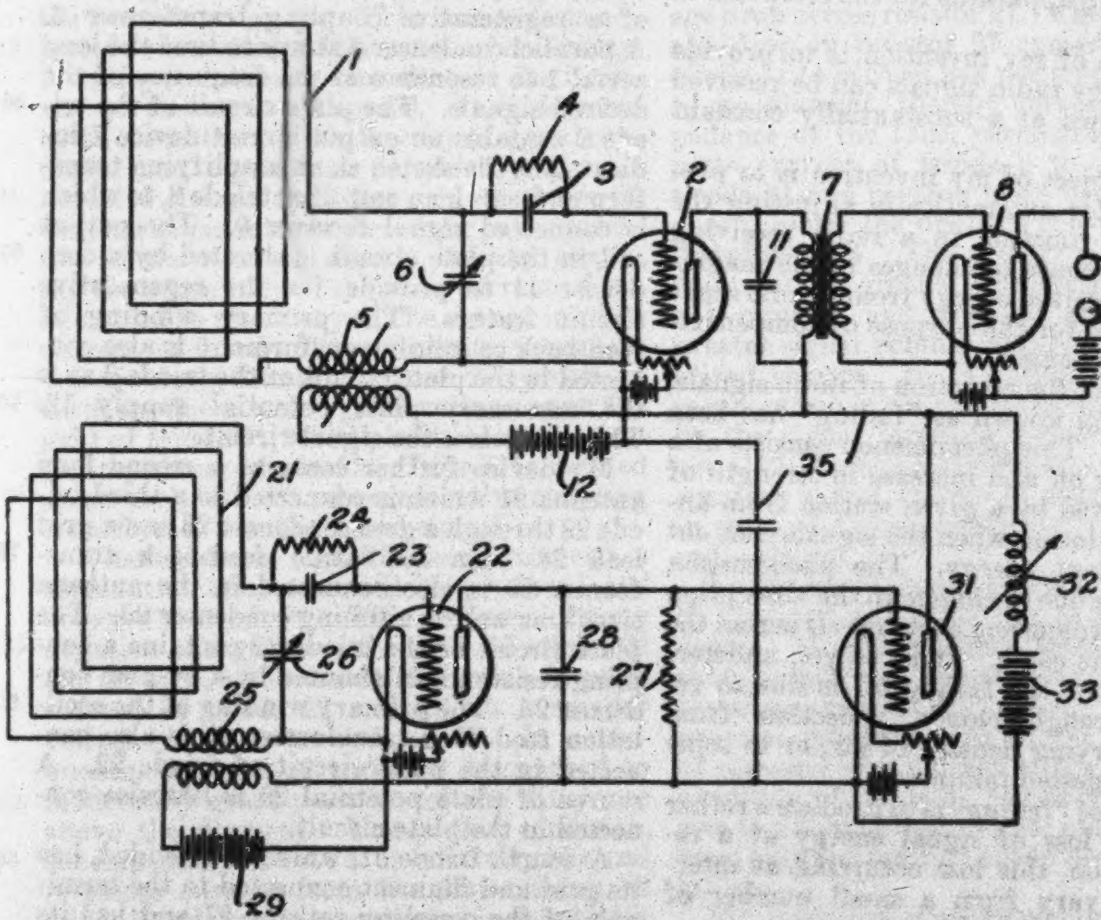
HERMAN A. AFFEL.

Jan. 8, 1929. 1,698,014

F. B. FALKNOR

RADIO SYSTEM

Filed March 13, 1924



WITNESSES:

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INVENTOR

Frank B. Falkner

BY

Wesley G. Carr

ATTORNEY

Patented Jan. 8, 1929. **1,698,014**

UNITED STATES PATENT OFFICE.

FRANK B. FALKNOR, OF WILKINSBURG, PENNSYLVANIA, ASSIGNOR TO WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY, A CORPORATION OF PENNSYLVANIA.

RADIO SYSTEM.

Application filed March 13, 1924. Serial No. 698,228.

My invention relates to radio systems and particularly to apparatus for the reception of radio signals.

One object of my invention is to provide means whereby radio signals can be received and maintained at a substantially constant volume.

Another object of my invention is to provide means for automatically adjusting the regenerative function in a radio receiving circuit in response to changes in the magnitude of the received energy from a radio sending apparatus for the purpose of compensating for such changes.

In the art of the reception of radio signals, a phenomenon known as "fading" has been encountered. This phenomenon consists of a cyclic falling off and increase in strength of signals received by a given station from another given station when the signals sent out are of constant energy. The phenomenon appears to be due to change in the absorption of the radio frequency as it travels across the surface of the earth. It is, as yet, undetermined whether the falling off is due to refraction through clouds, reflection from layers of varying density of air, or to some as yet unsuggested influence.

The effect of "fading" is to produce a rather troublesome loss of signal energy at a receiving station, this loss occurring at intervals which vary from a small number of minutes to a number of hours.

My invention provides means for overcoming the effect of fading upon the received signals. My apparatus is to be applied to a regenerative radio receiver, preferably of the type embodying a loop aerial and a regenerative feed-back, and consists of apparatus for varying the amount of regeneration produced, in response to changes in received signal energy. This result is secured by adjusting the value of a resistive shunt about the regenerative feed-back coil in response to changes in signal energy picked up by another radio receiver.

Other objects and structional details of my invention will be apparent from the following description when read in connection with the accompanying drawings, wherein:

The single figure is a diagrammatic view of circuits and apparatus embodying my invention.

In the figure, a loop aerial 1 is connected to a detector triode 2 through a grid condenser 3 and a grid leak 4, and through the grid coil of a regenerative coupling transformer 5. A parallel condenser 6 serves to tune the loop aerial 1 to resonance at the frequency of the desired signals. The plate circuit of the triode 2 contains an output circuit device 7 indicated in the sketch as an amplifying transformer feeding an amplifier triode 8, to which is connected signal receiver 9. The output coil in the plate circuit is shunted by a condenser 11 to provide for the regenerative circuit feature. The primary winding of feed-back coupling transformer 5 is also connected in the plate circuit of the triode 2 as is the customary plate potential supply 12. This comprises the signal circuit.

My device further contains a second loop antenna 21 which is connected to a third triode 22 through a grid condenser 23 and a grid leak 24. An oscillation feed-back transformer 25 is also connected in the antenna circuit as well as a tuning condenser 26. The plate circuit of the triode 22 contains a coupling resistance 27 shunted by a by-pass condenser 28. The primary winding of the oscillation feed-back transformer 25 is also connected in the plate circuit of triode 22. A source of plate potential 29 is likewise connected in the plate circuit.

A fourth triode 31, which is provided, has its grid and filament connected to the terminals of the coupling resistor 27 and has its plate and filament connected in shunt across the primary of the regenerative coupling transformer 5. The plate circuit of the triode 31 contains also a plate tuning inductance 32 and the customary source of plate voltage 33. This comprises the regulating circuit.

Triodes 2, 8, 22 and 31 are provided, as customary, with filament heating and control means, as indicated.

In the operation of my device, I energize triodes 2 and 8, thereby placing the signal circuit in condition for operation. I then adjust the condenser 6 to bring the tuning of the oscillating circuit, comprising the loop 1, the condenser 6 and the secondary coil of transformer 5, to resonance with the desired signals. Upon the arrival of signals, they are received by this circuit, detected by the triode 2 and its associated circuits, amplified by triode 8 and perceived by the operator through signal receiver 9.

I then adjust the coupling between the coils of transformer 5 to give maximum regeneration. This energizes the signal circuit with signal energy, which, however, is subject to variation in strength due to "fading" of the received signal energy. To compensate for this "fading", I then energize the triodes 22 and 31, adjust the condenser 26 for a radio frequency and increase the coupling between the primary and secondary coils of oscillation coupling transformer 25 until the circuit is set into oscillation at a frequency which gives a beat note with the radio frequency energy of the incoming signals. This beat note is adjusted to be outside of the range of audibility. It varies in intensity according to the intensity of the received signals. It is detected by triode 22 through the agency of a grid condenser and a grid leak 24 which produce a negative charge upon the grid of triode 22 varying in magnitude according to the intensity of the received signals, thereby changing the magnitude of the plate current of triode 22 in the usual way. The change in plate current of triode 22 produces a change in voltage drop through resistor 27, which, in turn, produces a change of voltage upon the grid of triode 31, which, in its turn, changes the impedance of tube 31. Tube 31 is shunted about the plate coil of regenerative coupling transformer 5 in the signal circuit.

When a strong signal is being received, a substantial beat note will be produced and detected in triode 22. This produces a strong negative charge upon the grid of triode 22 and in turn, a substantial reduction in plate current of triode 22 and allows a smaller voltage drop across resistor 27. In consequence, the grid of triode 31 is charged to moderately great positive voltage difference above the filament. Under this condition, the impedance of tube 31 is relatively low and it passes current from the plate circuit of triode 2 and since it is connected in shunt with the plate coil of oscillation coupling transformer 5 by conductors 35, it thereby causes less than maximum regeneration to be produced.

The average potential of the grid in the triode 21 depends upon the size of the condenser 23, of the resistor 24 and of the impressed alternating potential. The alternating potential impressed by the action of the coupling transformer 25 is modified by the potential received from the loop 21. It will, therefore, vary with the strength of the signal. The output current of the triode 22 will be a direct current from the battery 29 upon which is superposed the alternating current produced by the fluctuations of the grid potential. The effect of this superposition is to alter the average value of the output current. The average potential across the resistor 27 is dependent upon the average current in the output of the triode 22. The combination of condenser 28 and resistor 27 acts as an integrating device with the result that the grid of the tube 31 has a potential corresponding to the average condition of the output circuit of the triode 22 instead of following the instantaneous values of the current in said output.

When, however, the received signals begin to "fade", the signal intensity received by the loop antenna 21 results in a lower strength of beat note in the triode 22, a smaller charge on the grid of the triode 22, a greater plate current through triode 22 and a greater voltage drop across resistor 27. The greater voltage drop in resistor 27 causes the grid of triode 31 to become less positive with respect to its filament, thereby increasing the impedance of the tube, permitting less of the plate current of triode 2 to pass through triode 31 and causing more plate current to pass through the primary coil of oscillation transformer 5. The greater current in this coil produces greater regeneration in the signal circuits and thereby proportionately greater signal volume with respect to the received energy. In this way, the degree of regeneration in the signal circuit is controlled by the signal intensity received upon loop aerial 21, thereby maintaining a substantially constant signal volume in signal receivers 9 in spite of fading occurring in the received radio energy.

Furthermore, the response of my device is to "fading" only, and not to differences in degree of modulation, since modulation changes only the instantaneous amplitude of the signal current and not the integrated or average current. The slight sluggishness of response of a blocked triode, which is the condition of triode 31, causes it to be responsive to the integrated signal only, and, therefore, only to "fading" not to degree of modulation.

My invention is particularly adaptable to short-wave reception, such as the reception of signals at 100 meters wave length, at which wave length "fading" is particularly troublesome.

In practice, my invention makes it possible to maintain substantially constant signal energy. It is particularly adaptable to the reception of voice modulated signals, since it is responsive only to actual "fading" and it is not responsive to changes in modulation of the signal output. It thereby compensates for the "fading" but leaves the changes in sound volume due to modulation, unaffected.

While I have shown only one embodiment of my invention, it is capable of various changes and modifications without departing from the spirit thereof. I desire, therefore, that only such limitations shall be imposed thereon as are indicated in the appended claims.

I claim as my invention:

1. A radio signal receiving system comprising a radio receptor circuit, a radio detector, a set of regenerative circuits interlinking said receptor and said detector, and means for automatically adjusting the degree of regeneration to maintain a constant volume of output signals, said means comprising a second radio receptor circuit, a second radio detector, a second set of interlinking circuits adapted to produce oscillations in said second detector and said second receptor, a triode resistively coupled to said second detector, and connections shunting said triode across one of said regenerative circuits.

2. A radio receiving system comprising a radio receptor, a triode radio detector, a set of connecting circuits therebetween, a regenerative coupling transformer having plate and grid coils connected in said circuits and an adjustable resistive shunt connected across the plate coil of said coupling transformer, said adjustable resistor comprising a triode thermionic discharge device, and means whereby the conductivity of said triode discharge device is controlled by incoming signals.

3. A radio receiving system comprising a radio receptor, a triode radio detector, a set of interlinking circuits, a regenerative coupling transformer having plate and grid-coils connected in said circuits, an adjustable resistive shunt connected across the plate coil of said coupling transformer, said adjustable resistive shunt comprising a triode thermionic discharge device, a second oscillatory radio receiver comprising a second radio receptor, a second radio detector and a second interlinking oscillatory circuit, said second receiver being connected to said triode, whereby the signal-volume output from the main receiving circuit is automatically maintained substantially constant whenever the amplitude of the incoming oscillations varies from so-called fading effects.

4. In a signal-receiving system, means including a thermionic tube for deriving an indication from an incoming signal, separate means including a thermionic tube for deriving a potential proportional to the amplitude of said signal, and means whereby the gain in said first thermionic tube is controlled by said derived potential.

5. In a signal-receiving system, means including a thermionic tube for deriving an indication from an incoming signal, separate means including a thermionic tube for deriving a potential that various with the amplitude of said signal, and means whereby the potentials applied to the grid of said first thermionic tube are controlled by said derived potential.

In testimony whereof, I have hereunto subscribed my name this 5th day of March 1924.

FRANK B. FALKNOR.

Aug. 12, 1930. R. S. OHL **1,772,517**

RADIO RECEIVER

Filed Feb. 20, 1926

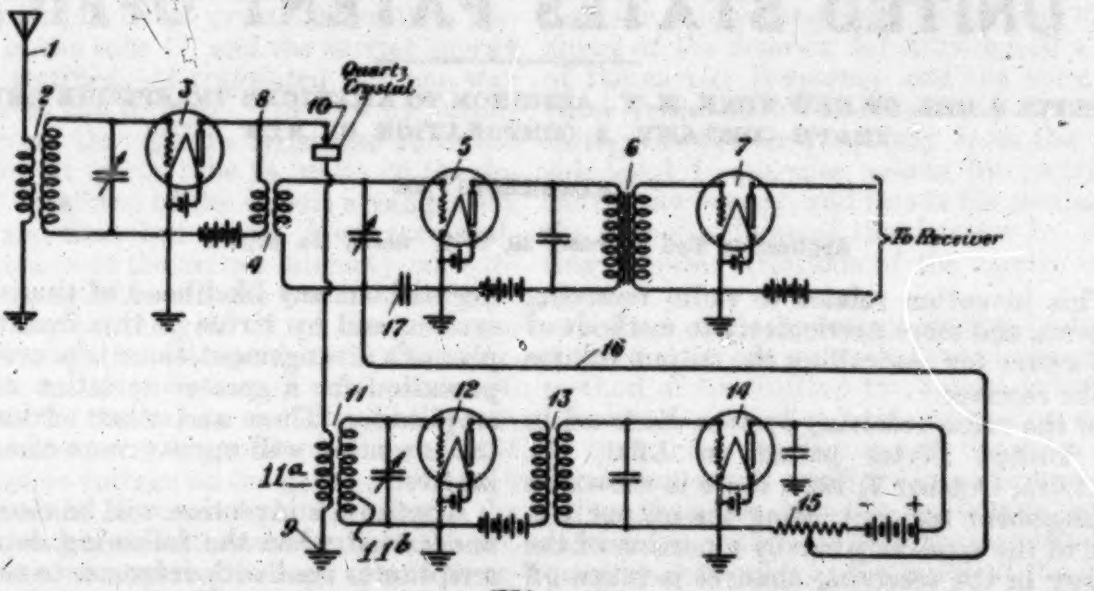


Fig. 1

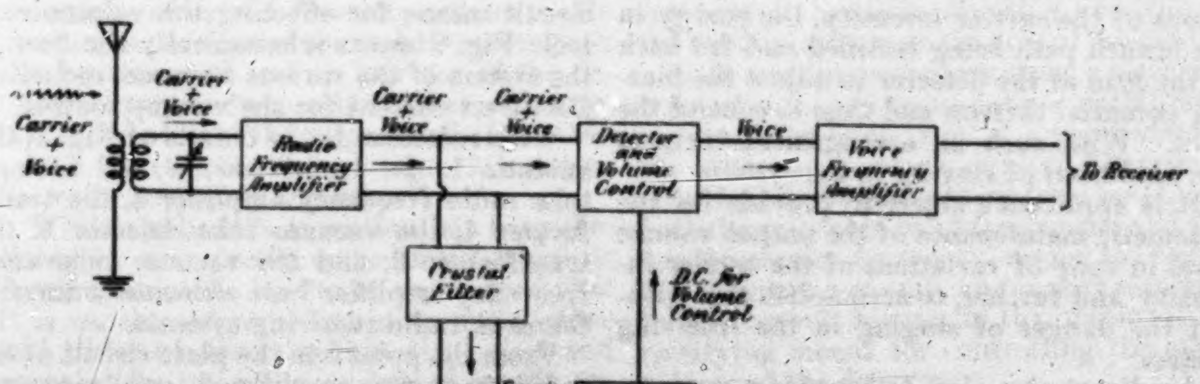


Fig. 2

INVENTOR
R. S. Ohl
BY
ATTORNEY

Patented Aug. 12, 1930 1,772,517

UNITED STATES PATENT OFFICE

RUSSELL S. OHL, OF NEW YORK, N. Y., ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK

RADIORECEIVER

Application filed February 20, 1926. Serial No. 89,794.

This invention relates to radio receiving systems, and more particularly to methods of and means for controlling the output volume of the receiver.

In the radio receiving system disclosed in the United States patent to Affel, No. 1,511,015, October 7, 1924, there is shown an arrangement for controlling the output volume of the receiver whereby a portion of the energy in the receiving channel is taken off after it has been passed through the detector and an amplifier and is then utilized to effect volume control in accordance with the fluctuations of the carrier intensity, the energy in the branch path being rectified and fed back to the grid of the detector to adjust the biasing potential thereon and thus to control the gain. With such an arrangement there is the likelihood of singing in the system.

It is applicant's object to provide for the automatic maintenance of the output volume level in spite of variations of the carrier intensity, and further, to accomplish this without the danger of singing in the receiving system.

Applicant also aims to provide a more reliable control of the output volume, and with this aim in view utilizes means new in this connection for selecting more sharply than has been done heretofore the carrier frequency component which is to be rectified and impressed upon the detector to effect the desired variation of grid potential.

Applicant accomplishes his purpose by providing a branch path from the receiving channel at a point in the system ahead of the detector, for instance from the output circuit of the radio frequency amplifier; placing in this branch path a quartz crystal which filters out the voice side-bands; amplifying the carrier current; rectifying the carrier energy, and causing variations of the carrier intensity automatically to produce offsetting variations of the negative biasing voltage on the grid of the detector, whereby the output volume of the detector is maintained substantially constant.

Applicant's invention not only overcomes fading due to variations of the carrier intensity, as does Affel's, but it overcomes fading without any likelihood of singing in the system, and by virtue of this feature of applicant's arrangement, there is provided compensation for a greater variation of carrier amplitude. These and other advantages of the invention will appear more clearly hereinafter.

Applicant's invention will be more clearly understood when the following detailed description is read with reference to the accompanying drawing. Figure 1 of the drawing shows diagrammatically the circuit arrangements of the receiving system, including the circuit means for effecting the volume control; Fig. 2 shows schematically the flow in the system of the various currents, including the direct current for the volume control.

With reference to the details of Fig. 1, the antenna 1, the transformer 2, the vacuum tube radio frequency amplifier 3, the transformer 4, the vacuum tube detector 5, the transformer 6, and the vacuum tube voice frequency amplifier 7 are elements ordinarily found in radio receiving systems.

From the point 8 in the plate circuit of the radio frequency amplifier 3, applicant provides a lead to ground at 9, and places in this branch path of the amplifier output a quartz crystal 10 and the primary winding 11^a of the transformer 11. The secondary winding 11^b of the transformer 11 serves as the input to the vacuum tube amplifier 12, which is inductively connected through the transformer 13 to the vacuum tube 14. In the plate circuit of the tube 14 is placed a resistance 15, from which a wire 16 leads to the grid circuit of the detector tube 5.

The operation of applicant's system will now be described, reference being had to Fig. 1 for a diagrammatic showing of the apparatus involved, and to Fig. 2 for a schematic showing of the current flow in the system. The incoming radio signals are amplified in the tube 3. There are two possible channels in the output circuit of this amplifier, the one into the detector 5 and the other through the quartz crystal 10 into the amplifier 12. The resonance properties of the quartz crystal are dividedly marked. The device serves as a filter, beginning to cut off frequencies ten

cycles to either side of the carrier, and frequencies of approximately sixty cycles to either side of the carrier are greatly attenuated. Consequently, the crystal serves to filter out the voice side-band frequencies and to pass the carrier frequency. In accordance with applicant's arrangement, the carrier current output of the crystal filter 10 is amplified in the tube 12, and the carrier energy is then rectified—or translated into one-way energy—in the tube 14. The flow of pulsating current through the resistance 15 in the plate circuit of the tube 14 reacts on the detector 5 by virtue of the circuit arrangement shown and described above. More specifically, variations of the carrier intensity cause responsive variations in the amount of negative biasing on the grid of the detector tube 5, because of the voltage drop in the resistance 15, in the plate circuit of the tube 14. Thus, when the carrier intensity increases, there is automatically produced an increase of the negative voltage on the grid of the tube 5 because of the increase of plate current in the tube 14, and, as is well understood in the art, this increased negative voltage serves to reduce the current flow in the plate circuit of the detector tube. Consequently, the output level of the detector is lowered. Conversely, a decrease of carrier intensity automatically produces a decrease of the negative voltage on the detector grid and an increase of the detector output volume. It follows of course that this control of the output level of detector tube 5 likewise controls the speech input to the voice frequency amplifier 7.

While applicant's invention has been disclosed in one specific embodiment which is deemed desirable, it is to be understood that it is capable of embodiment in many other and different forms within the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. In a radio receiving system, a three-electrode vacuum tube detector, means included in the system ahead of the detector for drawing off a part of the carrier frequency and the voice side-band frequencies combined and for separating the carrier frequency from the voice side-band frequencies, and means for controlling the biasing voltage on the grid of the detector in response to and as an offset to variations of the carrier intensity.

2. In a radio receiving system, a three-electrode vacuum tube detector, means ahead of the detector for passing a part of the carrier frequency and the voice side-band frequencies combined into a branch path, means for passing the balance of the carrier frequency and voice side-band frequencies combined to the input of the detector, means in said branch path for filtering out the voice side-band frequencies, means for rectifying the carrier energy, and means responsive to the current flowing in the output of said rectifying means for controlling the biasing voltage on the grid of the detector.

3. In a radio receiving system, a detector and a circuit arrangement for maintaining substantially level the output volume of said detector, said arrangement comprising means ahead of the detector for drawing off a part of the carrier frequency and the voice side band frequencies combined and for separating the carrier frequency from the voice side-band frequencies, means for rectifying the carrier energy, and means for controlling the output volume of the detector by offsetting therein variations of the carrier intensity.

4. In a radio receiving system including a three-electrode vacuum tube detector, the method of controlling the output volume of the detector which consists in passing a part of the carrier frequency and the voice side-band frequencies combined into a branch path before detection, passing the balance of the carrier frequency and the voice side-band frequencies combined to the input of the detector, filtering out in said branch path the voice side-band frequencies, rectifying the carrier energy, and causing variations of the carrier intensity to produce offsetting variations of the biasing voltage on the grid of the detector.

5. In a radio receiving system, a main path, a detector in said main path, a path branching from the main path at a point ahead of the detector, a quartz crystal filter in the branch path for eliminating from said branch path the voice side-band frequencies and passing the carrier frequency, means for rectifying the carrier energy, and means responsive to the current flowing in the output of said rectifying means for controlling the output volume of the detector.

6. In a radio receiving system, a main path, a three-electrode vacuum tube detector in said main path, a path branching from the main path at a point ahead of the detector, a quartz crystal filter in the branch path for eliminating from said branch path the voice side-band frequencies and passing the carrier frequency, means for rectifying the carrier energy, and means for increasing and decreasing the negative biasing voltage on the grid of the detector in response to increases and decreases, respectively, of the current in the output of said rectifying means.

In testimony whereof, I have signed my name to this specification this 18th day of February, 1926.

RUSSELL S. OHL.

July 17, 1928. 1,677,224

H. A. AFFEL

CARRIER RECEIVING SYSTEM

Filed March 23, 1926

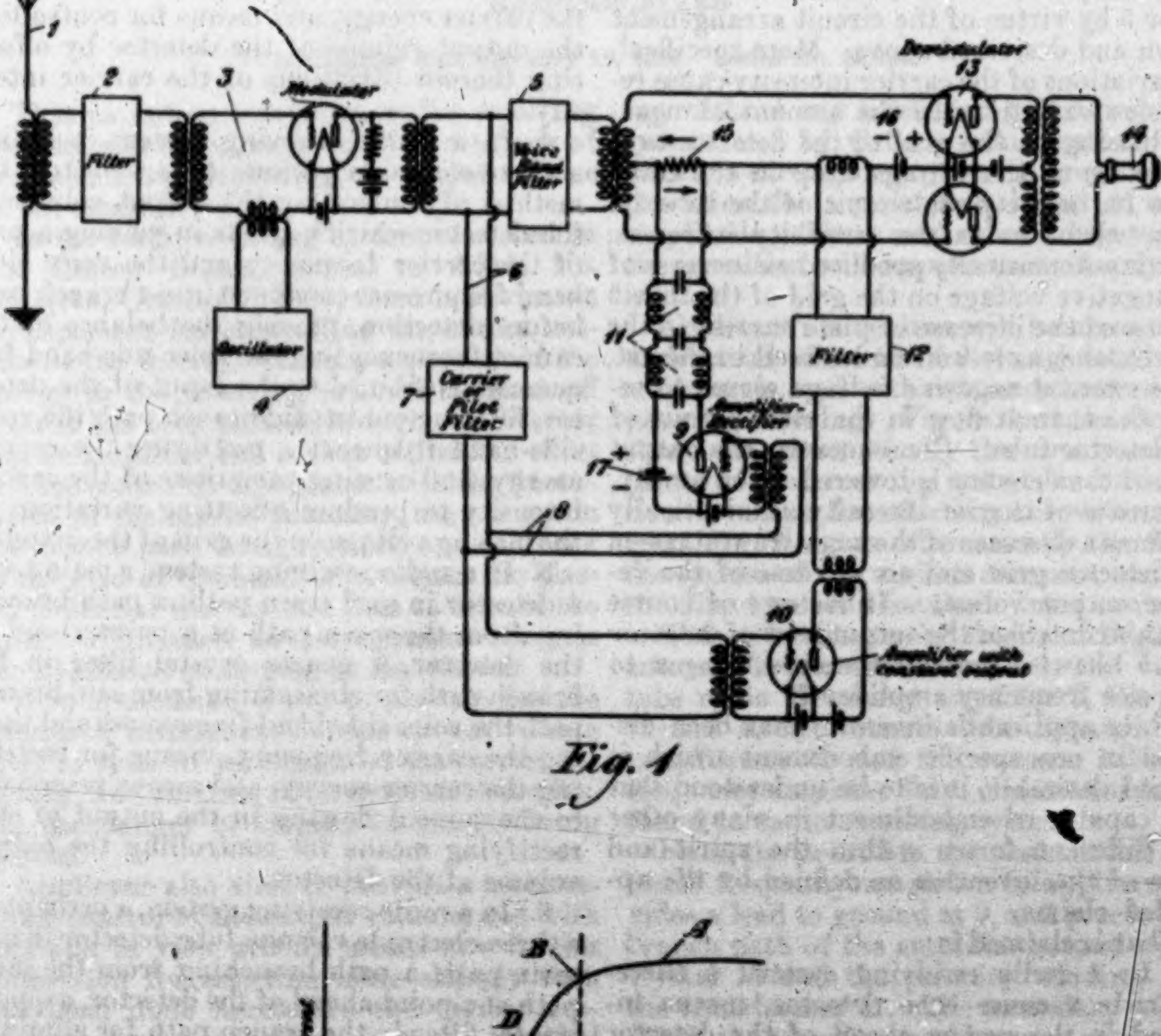


Fig. 1

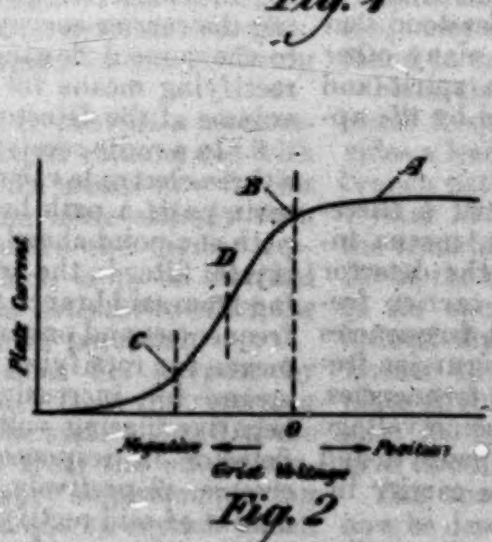


Fig. 2

INVENTOR
H. A. Affel

BY G. E. Folk

ATTORNEY

Patented July 17, 1928. 1,677,224

UNITED STATES PATENT OFFICE.

HERMAN A. AFFEL, OF MAPLEWOOD, NEW JERSEY, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

CARRIER-RECEIVING SYSTEM.

Application filed March 23, 1926. Serial No. 96,887.

This invention relates to arrangements for stabilizing the overall transmission equivalent of long distance carrier or radio telephone circuits, or in other words, to compensate for the fluctuations in transmission or fading effects experienced in such circuits. The invention is particularly applicable to the case of a very long circuit, such as a transatlantic circuit, using relatively low frequencies and carrier suppression method of operation.

In accordance with the arrangements of this invention, at the transmitting station, instead of providing for complete suppression of the carrier, sufficient carrier current is permitted to flow into the transmitting antenna circuit to provide a pilot frequency which is used at the receiving circuit as a means of stabilizing the output thereat. This pilot frequency is also utilized at the receiving station to provide the necessary demodulating frequency. In addition to stabilizing the receiver output and overcoming fading effects, or fluctuations in transmission, the arrangements of the invention present other distinct improvements over former systems in that the transmitted carrier current required for the above mentioned purposes need only be relatively weak as compared to the carrier current which would be transmitted to the line in a regular carrier transmission type of system, in which case the carrier energy must represent several times the voice energy in order to insure sufficient carrier in a self-detection type demodulator for good quality speech. By permitting only a relatively small amount of carrier to flow as compared with the side-band energy, a very beneficial result will be apparent with respect to the amplifiers at the transmitting station, as the capacity of these amplifiers will be governed substantially by the useful side-band energy alone. Other features and purposes of the invention will appear more fully from the following detailed description thereof.

The invention may be more fully understood from the following description, together with the accompanying drawing, in the Figures 1 and 2 of which the invention is illustrated. Fig. 1 is a circuit diagram of a receiver circuit embodying the invention, while Fig. 2 illustrates graphically the operating characteristics of one of the demodulators.

As has been previously pointed out, the carrier component at the transmitting station will not be completely suppressed and a portion thereof will accordingly be received at the antenna 1 of Fig. 1. This incoming energy will be transmitted through a circuit including the filter 2, which is provided for the purpose of discriminating against the incoming frequencies of other stations which are not wanted and which might overload the modulator 3 into which the desired signal is next led. This modulator circuit 3 is provided with the oscillator 4 which provides a beating frequency which will cause a step-down of the radio signal frequency to a relatively low frequency, say for example, of the order of 5000 cycles. This is done because at this lower frequency selecting circuits can be made to effectively operate with only a hundred cycles or so available for separating the side band and carrier frequencies. The stepped-down signal is then led into two selective circuits, one of which includes the filter 5 which will transmit a side band, and another of which, the circuit 6, includes the filter 7 which will transmit the carrier or pilot frequency. The side band is transmitted through filter 5 to the input of a duplex vacuum tube demodulator 13 of the type illustrated in the United States Patent No. 1,343,306, to J. R. Carson. The output circuit of the demodulator 13 is associated with a receiver circuit including the receiver 14.

The carrier or pilot frequency is transmitted over the circuit 6 which includes the filter 7, which will pass the carrier frequency, as stepped down, but will not pass the side-band frequencies. This carrier or pilot frequency is now employed for two purposes. It is transmitted to the input of an amplifier 10, which has its constants so arranged, as is well known in the art, as to be of the overload type with substantially constant output for varying input energy. Hence, regardless of fluctuations in transmission and fading effects, the output energy from the tube 10 will be constant. In the output circuit of tube 10 will be provided a filter 12 to suppress harmonics of the pilot frequency which might be caused by the action of a tube of this type. This constant pilot frequency will then be applied to the demodulator circuit as shown, to which the side band frequencies have been transmit-

ted and demodulation will take place in a well-known manner.

Another portion of this pilot or carrier frequency is transmitted over circuit 8 to an amplifier-rectifier tube 9. The pilot frequency is hereby rectified and then transmitted through the low pass filter 11 and through a resistance 15 included in the grid circuits of the demodulator 13, whereby it may control the potential of the grids. In other words, the pilot frequency is utilized in this manner to control the effective gain of the demodulator circuit. This may be more fully understood from reference to Fig. 2, wherein is shown graphically a curve A illustrating the operating characteristics of the demodulator 13. At point B on the curve the grid voltage is zero. At a point such as C near the knee of the curve, the grid voltage is negative. It is at this point that the demodulator operates at optimum value. Accordingly it will be seen that any decrease in the negative voltage to a point such as D would cut down the effective gain of the demodulator. Consequently, the grid battery 16 is adjusted so that the demodulator will function at optimum value when the incoming energy is of normal magnitude. Any increase in the incoming energy above normal would result in an increased flow of current in the plate circuit of the rectifier tube 9. It will be seen that the connections to resistance 15 are such that the voltage drop through that resistance due to current flowing in the output of the rectifier tube will oppose the voltage of the battery 16. This is indicated by the arrows. Accordingly, an abnormal increase in the incoming energy will serve to so increase the current opposing that of the grid battery that the negative grid voltage will be reduced, for example, to a point such as D, and the demodulator gain will be cut down. Conversely the gain will be increased in the case of an incoming weak signal. In this manner the received carrier acting as a pilot channel is utilized both for purposes to gain control and synchronization.

While the invention has been illustrated in certain specific forms which are deemed desirable, it is understood that it is capable of embodiment in many and other widely varied forms without departing from the spirit of the invention as defined in the appended claims.

What is claimed is:

1. The combination of a carrier transmitting station wherein the carrier frequency is only partially suppressed and a carrier receiving station comprising a modulator for reducing the frequency of the incoming signal wave, a selective circuit associated with the output of said modulator and adapted to transmit the side band component of said reduced signal wave, a second selective circuit associated with the output of said modulator and adapted to transmit the carrier component of said reduced signal wave, a demodulator having its input circuit associated with said side band selective circuit, a rectifier associated with said second selective circuit whereby said carrier component may be rectified, and means to apply said rectified carrier component current to the grid circuit of said demodulator so that the voltage of said rectified current will oppose the normal grid voltage.

2. The combination of a carrier transmitting station wherein the carrier frequency is only partially suppressed and a carrier receiving station comprising a modulator for reducing the frequency of the incoming signal wave, a selective circuit associated with the output of said modulator and adapted to transmit the side band component of said reduced signal wave, a second selective circuit associated with the output of said modulator and adapted to transmit the carrier component of said reduced signal wave, a demodulator having its input circuit associated with said side band selective circuit, an amplifier having a constant output characteristic included in said second selective circuit, means to associate the output of said amplifier with said demodulator so that the carrier component transmitted therethrough will operate as a beating frequency, a rectifier associated with said second selective circuit whereby said carrier component may be rectified, and means to apply said rectified carrier component current to the grid circuit of said demodulator so that the voltage of said rectified current will oppose the normal grid voltage.

3. The method of stabilizing the volume output of a receiving set in a carrier system in which the transmitted carrier is partially suppressed, which consists in separating at said receiving set the carrier component and the side band component, subjecting the side band component to demodulation, rectifying the carrier component, and utilizing the voltage of the rectified carrier component to oppose the grid voltage utilized for demodulating said side band component.

In testimony whereof, I have signed my name to this specification this 22nd day of March, 1926.

HERMAN A. AFFEL.

July 12, 1932. H. J. J. M. DE R. DE BELLESCIZE 1,867,139

RADIO RECEIVING APPARATUS

Original Filed March 30, 1927

Fig. 1

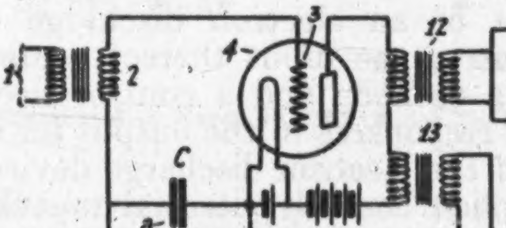


Fig. 2

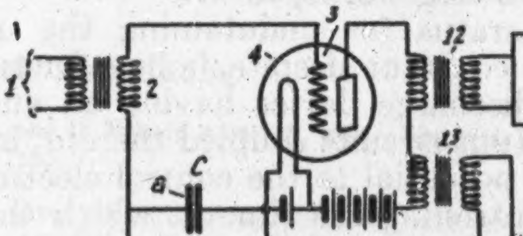
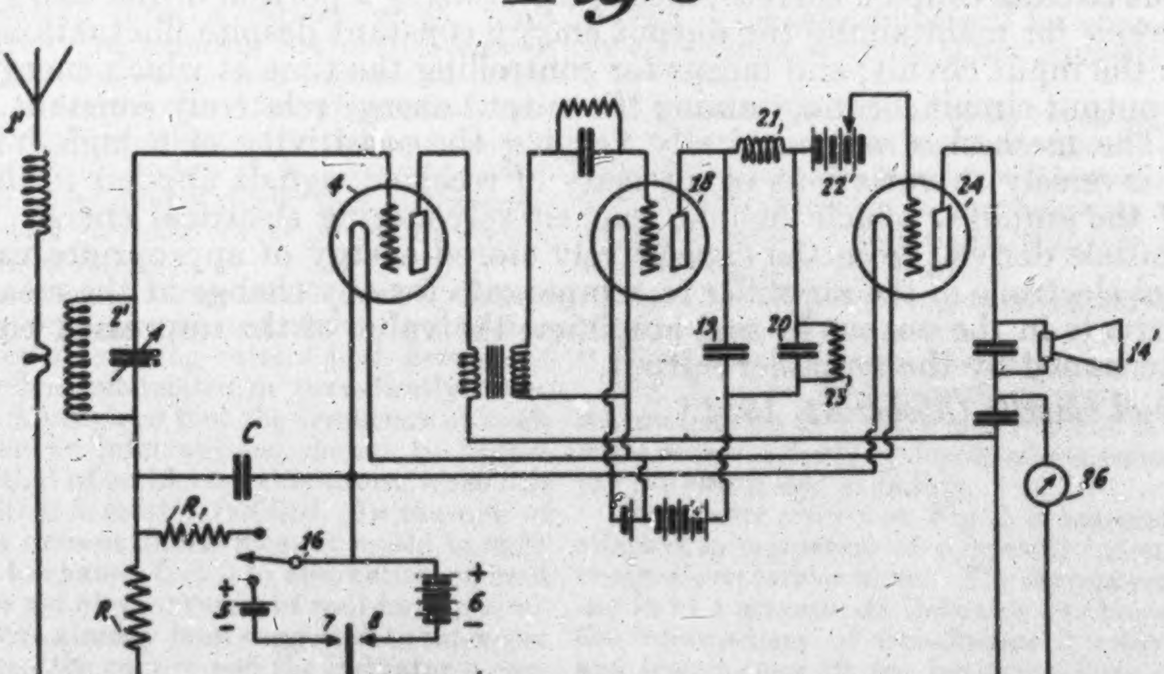


Fig. 3



INVENTOR

H. J. J. M. de R. de BELLESCIZE

BY

ATTORNEY

DISCLAIMER

1,867,139.—*Henri Jean Joseph Marie de Regnauld de Bellescize*, Paris, France. RADIO RECEIVING APPARATUS. Patent dated July 12, 1932. Disclaimer filed September 30, 1933, by the assignee, *Radio Corporation of America*.

Hereby enters this disclaimer to the said claims of said Letters Patent which are in the following words, to-wit:

"5. Apparatus for maintaining the output of an electron discharge device substantially constant despite fading fluctuations in the input thereof comprising, an electron discharge device having an anode, a cathode and a control electrode; input and output circuits coupled thereto; means responsive to the output for applying a control potential to the control electrode of the electron discharge device; and means for controlling the time at which the applied control potential makes itself manifest upon the control electrode.

"6. Apparatus for maintaining the output of an electron discharge device substantially constant despite fading fluctuations in energy supplied to the input thereof comprising, an electron discharge device having an anode, a cathode, and a control electrode; input and output circuits coupled thereto; means for controlling the amplification of the device inversely to the average amplitude of the output thereof; and means for controlling the speed of action of the said last mentioned amplification control means.

"7. Apparatus for maintaining the output of an electron discharge device substantially constant despite fading fluctuations in the input thereof comprising an electron discharge device having an anode, a cathode, and a control electrode; input and output circuits coupled thereto; means for utilizing a portion of the energy in the output circuit for maintaining the output energy constant despite fluctuations in the energy in the input circuit; and means for controlling the time at which energy taken from the output circuit for maintaining the output energy relatively constant, acts.

"8. The method of automatically varying the sensitivity of a high frequency amplifier inversely to variations of intensity of received signals applied to the input circuit of the amplifier which includes capacitively storing electrical energy, impressing potentials derived from the capacitively stored energy of appropriate values on the control electrode of the amplifier to compensate for any change in the mean value of the currents in the output of said amplifier; the value of the impressed potentials being determined by the amplifier output."

[*Official Gazette October 31, 1933.*]

Patented July 12, 1932 1,867,139

UNITED STATES PATENT OFFICE

HENRI JEAN JOSEPH MARIE DE REGNAULD DE BELLESCIZE, OF PARIS, FRANCE, ASSIGNOR TO RADIO CORPORATION OF AMERICA, OF NEW YORK, N. Y., A CORPORATION OF DELAWARE

RADIORECEIVING APPARATUS

Application filed March 30, 1927, Serial No. 179,469, and in France April 13, 1926. Renewed September 16, 1930.

This invention relates to receiving apparatus and more particularly to an arrangement associated therewith for compensating the effects due to fading.

In certain equipments fed with alternating current or alternating current potentials of sinusoidal wave form, either modulated or periodically interrupted, it happens on account of certain accidental causes that the current or the alternating current potential is subject to more or less great variations in amplitude. Now, it is often necessary, with a view to preserve the apparatus, for the sake or regulation or simply of the quality of reproduction, that the indicator apparatus should carry a current which, while faithfully reproducing the modulations or interruptions of the feed currents or potentials, is entirely freed or safeguarded from accidental variations of its mean amplitude.

Among such cases in which this problem arises, there figures chiefly that of transmission with Hertzian waves subject to what is known as fading.

The present invention discloses a solution to the problem which is useful for distribution by alternating current both permanent as well as modulated or periodically interrupted, provided that the frequency of modulation or interruptions should be higher than that of accidental alterations, when this condition is mostly fulfilled. In the case of direct current distribution, it would be sufficient to change first into alternating current by the aid of a converter of well-known kind.

It has already been suggested to interpose between the supply and the indicator a coupling means whose sensitiveness diminishes automatically as soon as the current in the indicator exceeds a certain pre-arranged value, and this reduction was ordinarily insured by the aid of a variable resistance. The inconvenience residing in devices of this kind consists in that to each value of the current in the indicator there corresponds one and only one value of the variable resistance, and therefore of the sensitiveness of the coupling means.

However, it is necessary, and this is accomplished by the present invention, that every increase or decrease, no matter how small in amount of the mean current or potential in the indicator, should be compensated by an increase or a decrease in sensitiveness of sufficient value in order to compensate for the slight departure that has given rise thereto. It is moreover desirable, once that the mean current in the indicator has been restored to the desired value, that the sensitivity of the transmission should be fixed to a predetermined value instantaneously assumed in order to insure such result, and this, until a fresh change in the supply current or potential occurs.

In other words, the supply current and current in the indicator should be connected by a transmission device acting similarly as a servo-motor.

The invention, both as to its construction and mode of operation together with the objects and advantages thereof, will best be understood by reference to the following description taken in connection with the accompanying drawing in which

Fig. 1 is a circuit arrangement embodying the features of my invention,

Fig. 2 is a modification thereof, and

Fig. 3 is an arrangement applying the schemes shown in Figs. 1 and 2 to Hertzian wave receivers for the purpose of compensating the effects due to fading.

The scheme shown in Fig. 1 is especially adapted to regulation of sinusoidal currents or signals on carrier waves. The current coming in at 1 actuates an indicator 14 through the intermediary of transformer 2, relay 4 and transformer 12, the latter coupling the output of relay 4 and indicator 14. The relay 4 may be, for instance, an arc relay, or a vacuum tube, comprising one or more control electrodes. The sensitiveness of the relay depends upon the permanent potential applied to one of its electrodes 3, the said potential being derived from the plate *a* of condenser C, the charge of which therefore governs the sensitivity. In order that this charge may assume or preserve a convenient value at all instants, the condenser C is fed across a resistance R from one of the two sources 5 or 6 cut in the circuit by means of a mobile con-

tact or armature 10 adjusted by a spring 9 and bearing upon one of the contacts 7 or 8. The connection in circuit of the source 5 for a sufficiently long time imparts a maximum of sensitivity to the relay, while when source 6 is connected in circuit, the sensitivity is considerably diminished. (In the majority of relays, the maximum sensitivity is obtained by replacing the source 5 by a conductor connecting the contact 7 with the relay). The movable contact or armature 10 in turn is controlled by the output current of the relay through transformer 13. If the mean value of this current is unduly low, the armature will come to bear upon contact 7, and this results in a gradual increase in sensitivity to such an amount as may be required. If the current in the indicator is too high, the armature comes to bear upon contact 8 with the incidental result that the sensitivity is diminished. Finally, if the current preserves its pre-arranged value, the armature having but a small stroke or travelling distance, remains between contacts 7 and 8 so that the sensitivity remains unaltered, save for the losses occasioned in condenser C. By way of example, there is shown for the drove 11—9 of armature 10 a device of known kind adapted to thermal ammeters which by contacts 7—8 allows of regulation of the main valve of the current received by the indicator. Similarly as in a servo-motor, it is possible in this scheme to adjust the rate of variation of sensitivity by adjusting the time constant RC. This time constant must be considerably higher than the time of shift of contact 10, while it must be lower than the period of accidental alterations to be compensated.

Fig. 2 shows a modification adapted to the regulation of periodically interrupted currents such as the currents used in telegraphy work. For this purpose, the source 5 is omitted and the condenser C is shunted by a resistance R′ appreciably higher than the resistance R. As long as the current coming from the relay 4 is too low, the movable contact or armature 10 will never reach the contact 8 and the condenser C will get a chance to discharge completely into the resistance R′ whereby the sensitiveness of the relay is gradually increased to a maximum. On the contrary, in the course of transmission by unduly intensive signals, the armature 10 is incessantly in movement passing from contact 7 during spaces between signals to contact 8 while signals are proceeding. Hence, alternating discharges and charges take place in the condenser C, the latter changing it suddenly on account of the relation R′ and R. This differential action makes the relay gradually insensitive until the armature 10 no longer reaches the contact 8.

Fig. 3 illustrates an application of this regulator to a receiver acted upon by Hertzian waves and here shown only in its most elementary parts for the sake of clarity of illustration.

The signals on modulated or chopped waves are received by the antenna 1′ and the tuned circuit 2′, thence fed to the regulator tube 4, and thereafter detected by tube 18. If at this point, their intensity is not yet sufficient to actuate the armature 10, they may be amplified by one stage for direct current, comprising in well-known manner a relay 24, a plate resistance 23 and a source 22, capacities 19—20 and the coil 21 stopping the flow of radio frequency oscillations to the relay 11′ the proximity of which to tube 4 is liable to occasion oscillations. The relay 11′ may be of any desired type, for instance, of the moving coil type, and it is passed by a current I_p+I_s, (plate current and signal current, respectively). By tensioning more or less the spring 9 or shifting the row of contacts 7—8, it is possible to cause contact 7 to become operative for any desired value of the current less than the pre-arranged value I_p+I_s, and contact 8 for all higher values. A reverser 16 (commutator switch) allows of changing operating conditions from reception on carrier waves to operation and reception on broken waves. A milliammeter 26 is provided to insure proper operation. The indicator is shown at 14′ coupled capacitively to the output of relay 24.

By virtue of the automatic feature of the regulation here disclosed, it is possible for the receiver apparatus to handle signals of widely varying volumes without the necessity of manipulation of any kind, regardless of whether the corresponding station is located a few kilometers or a few thousand kilometers away.

This regulating device is indispensable to insure proper function of certain parts of receiving equipment, for instance, in the operation of the differential arrangement comprising frictional means disclosed in the French Patent No. 587,625 filed December 28, 1923; indeed, in the absence of such protective means, the excess of energy coming in on the signal at any given time is apt to derange the differential device. And when allowed to go too far, such excess of energy may even cause disappearance of the signals, according to the mechanism provided for disturbance and interference.

It must be noted that the present invention comprises all modifications, servo-motors, static elements, and other, adapted to automatically vary the sensitivity in the desired sense, in a continuous or intermittent manner, until the pre-arranged value for the indicator is restored.

Having thus described my invention, I claim:

1. Radio receiving apparatus of the class described, comprising a high frequency am-

plifier, an electromechanical relay controlled by the output of said amplifier, said relay having an armature connected to the control electrode of the amplifier, and a pair of contacts raised to different potentials arranged to cooperate with said armature, whereby variations in mean signal intensity will actuate the relay armature to contact with one or the other of said contacts to maintain the signal intensity substantially constant.

2. Radio receiving apparatus of the class described, comprising a thermionic amplifier, indicatng means coupled to the output thereof, and means for compensating for any variation in mean signal intensity in said indicating means comprising an electromechanical relay coupled to the amplifier output, a condenser connected between cathode and control electrodes of the amplifier, said relay having an armature connected to one terminal of the condenser, and a pair of contacts and polarizing means connected to the other terminal of the condenser, the relay armature normally assuming a position intermediate said contacts and contacting with one or the other thereof when the signal intensity in the amplifier output is above or below the mean signal intensity.

3. Radio receiving apparatus of the class described, comprising a high frequency amplifier, indicating means coupled to the output thereof, and means for compensating for any variation in mean signal intensity in said indicating means comprsing an electromechanical relay coupled to the amplifier output, a condenser connected between cathode and control electrodes of the amplifier, said relay having an armature connected to one terminal of the condenser through a resistance, and a pair of contacts and grid polarizing means connected to the other terminal of the condenser, the relay armature normally assuming a position intermediate said contacts and contacting with one or the other thereof when the signal intensity in the amplifier output is above or below the mean signal intensity.

4. In radio receiving apparatus of the class described, the combination with a high frequency amplifier, of an indicator coupled to the output of said amplifier, and means for compensating for any variation of the mean signal intensity in the indicator, said means comprising a condenser connected between cathode and control electrodes and an electromechanical relay controlled by the amplifier output for charging said condenser in proportion to resulting variations, said condenser charge arranged to influence the control electrode for maintaining the mean signal intensity substantially constant.

5. Apparatus for maintaining the output of an electron discharge device substantially constant despite fading fluctuations in the input thereof comprising, an electron discharge device having an anode, a cathode and a control electrode; input and output circuits coupled thereto; means responsive to the output for applying a control potential to the control electrode of the electron discharge device; and means for controlling the time at which the applied control potential makes itself manifest upon the control electrode.

6. Apparatus for maintaining the output of an electron discharge device substantially constant despite fading fluctuations in energy supplied to the input thereof comprising, an electron discharge device having an anode, a cathode, and a control electrode; input and output circuits coupled thereto; means for controlling the amplification of the device inversely to the average amplitude of the output thereof; and means for controlling the speed of action of the said last mentioned amplification control means.

7. Apparatus for maintaining the output of an electron discharge device substantially constant despite fading fluctuations in the input thereof comprising an electron discharge device having an anode, a cathode, and a control electrode; input and output circuits coupled thereto; means for utilizing a portion of the energy in the output circuit for maintaining the output energy constant despite fluctuations in the energy in the input circuit; and means for controlling the time at which energy taken from the output circuit for maintaining the output energy relatively constant, acts.

8. The method of automatically varying the sensitivity of a high frequency amplifier inversely to variations of intensity of received signals applied to the input circuit of the amplifier which includes capacitively storing electrical energy, impressing potentials derived from the capacitively stored energy of appropriate values on the control electrode of the amplifier to compensate for any change in the mean value of the currents in the output of said amplifier; the value of the impressed potentials being determined by the amplifier output.

9. Apparatus for maintaining the output of a high frequency amplifier including an electron discharge tube substantially constant despite fading fluctuations in the input thereof, said tube having an anode, a cathode and a control electrode, input and output circuits coupled thereto, a path including a visual current indicator and means responsive to the amplifier output for applying a control potential to the control electrode of said tube, and means for controlling the time at which the applied control potential makes itself manifest upon the control electrode.

10. Apparatus for maintaining the output of an electron discharge device substantially constant despite fading fluctuations in energy supplied to the input thereof comprising an electron discharge device having an anode, a cathode, and a control electrode input and

output circuits coupled thereto, a path including a visual current indicator and means for controlling the amplification of the device inversely to the average amplitude of the output thereof, and means for controlling the speed of action of the said last mentioned amplification control means.

11. In a high frequency receiving system, an electron discharge device having an anode circuit, a cathode and a grid, a tuned circuit connected between said cathode and grid whereby said receiving system may be adjusted to respond to current of a desired frequency, sound reproducing means, means for supplying current from said device to said sound reproducing means, means for controlling the static potential on said grid in response to the intensity of the received carrier thereby to produce a substantially constant volume of sound from said sound reproducing means over a range of intensities of received current, means responsive to the magnitude of current flowing in said anode circuit for visually indicating said magnitude, and additional means for controlling the time at which the static potential makes itself manifest on said grid.

12. In combination, in a radio receiver, a high frequency amplifier having a resonant input circuit, a detector having its input electrodes coupled to the output circuit of said amplifier, a reproducer, means for connecting the reproducer to the output of said detector, a path connecting said detector output to said resonant circuit of said amplifier, said path including a resistor for controlling the static potential on the grid of the amplifier in response to the intensity of received current thereby to produce a substantially constant volume of sound from said reproducer over a range of intensities of received current, a condenser connected to said resistor in the input circuit of said amplifier, said condenser having a magnitude such that the time at which the said static potential makes itself manifest on said grid is controlled, and a visual current indicator connected to said aforementioned path.

HENRI JEAN JOSEPH MARIE de REGNAULD de BELLESCIZE.

Oct. 21, 1930. E. BRUCE 1,778,750

TRANSMISSION REGULATION

Filed Dec. 31, 1926

Fig. 1.

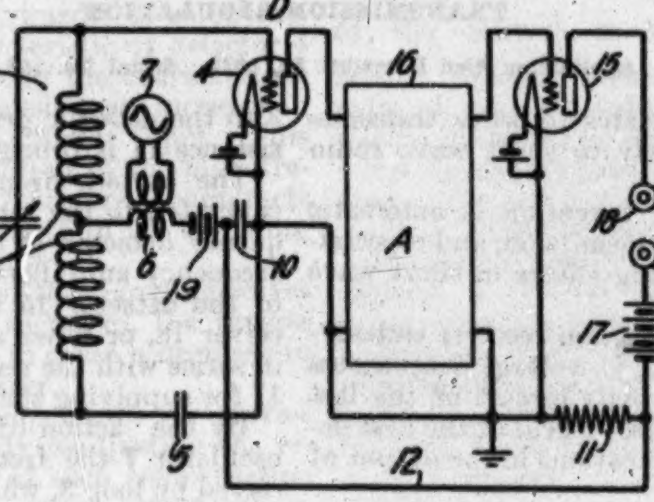
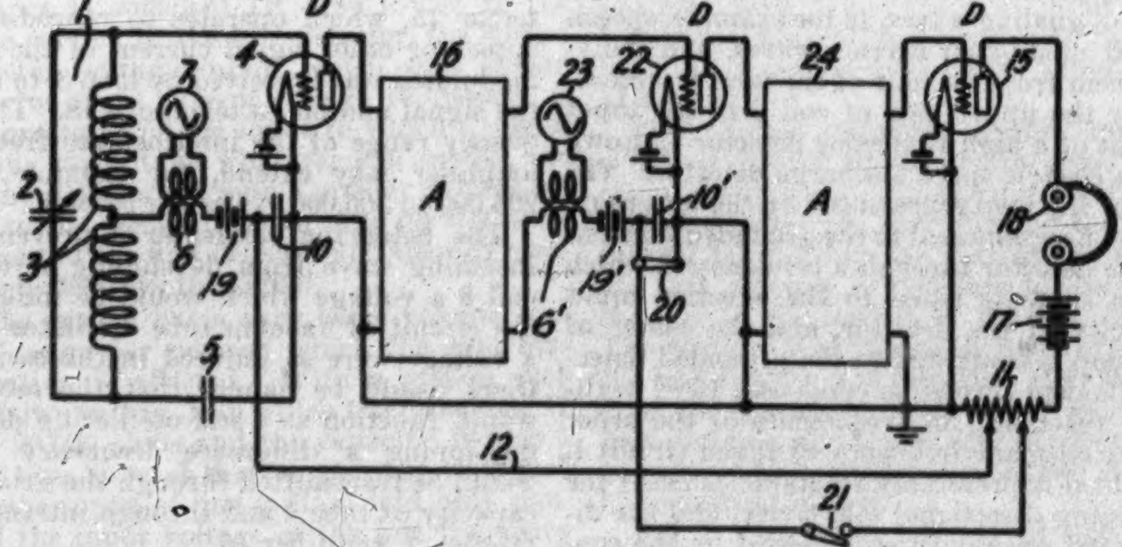


Fig. 2.



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Patented Oct. 21, 1930 1,778,750

UNITED STATES PATENT OFFICE

EDMOND BRUCE, OF RED BANK, NEW JERSEY, ASSIGNOR TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

TRANSMISSION REGULATION

Application filed December 31, 1926. Serial No. 158,169.

This invention relates to wave transmission, and particularly to short wave radio signaling.

An object of the invention is automatic volume control of transmission, and especially reduction of fading effects in short wave radio telephony.

In a successive detection receiver embodying the invention, D. C. voltage drop across a resistance in the plate circuit of the last detector variably biases a grid of the first detector, to reduce fluctuations in the output of the last detector.

Fig. 1 of the drawing shows a double detection receiver; and Fig. 2 shows a triple detection receiver embodying the invention.

In Fig. 1, a tuned circuit 1, comprising a variable tuning condenser 2 and a loop antenna represented as an inductance coil 3, receives radio signaling waves, as for example, speech signal modulated carrier waves, and delivers them from the half of the loop represented by the upper half of coil 3 to the input circuit of a high frequency detector 4, shown as an electric space discharge detector. The end of the loop represented by the lower end of coil 3 is connected to the grounded filament of the detector through a condenser 5 which has a capacity equal to the effective input capacity of the detector, and the center of the loop is connected to the grounded detector filament through a condenser 10 of negligible reactance for frequencies of the order of the resonant frequency of tuned circuit 1. The loop is preferably rotatable as usual for obtaining directional selectivity, and the directional selectivity is increased by the connecting of the center of the loop inductance to earth and the use of the condenser 5 for preventing unbalance of the capacities connected to the loop, with respect to ground. The detector A. C. input circuit includes a coil 6 coupled to a beating oscillator 7, preferably of the electric space discharge type, in series with a grid biasing battery 19 and the condenser 10. The D. C. connection between the filament and the grid of the detector 4 extends from ground through a resistance 11, conductor 12, the grid biasing battery 19 for the detector, coil 6, and upper half of coil 3 to the detector grid. The function of resistance 11 is brought out hereinafter.

The output circuit of the detector 4 is connected to the input circuit of a low frequency detector 15 through an intermediate frequency amplifier 16. The output circuit of the detector 15 includes a telephone receiver 18, or other signal indicating means, in series with the resistance 11 and a battery 17 for supplying space current to detector 15.

By the action of detector 4 and beating oscillator 7 the frequency of the waves received by loop 3, which may be, for example, of the order of 10^7 cycles per second is changed to a lower frequency, as for example, a frequency of the order of 300,000 cycles. These lower frequency waves, after selective amplification in an intermediate frequency amplifier 16, are delivered to detector 15, which operates to reproduce the speech or other signal current of the signal modulated wave received by loop 3, to render the signal audible in telephone 18. The frequency range of the intermediate frequency amplifier may extend, for example, from 295,000 to 305,000 cycles per second.

The balancing condenser 5 prevents the incoming wave from developing across the coil 6 a voltage which would be induced in the circuit of vacuum tube oscillator 7. If a voltage were so induced in the oscillator, there would be danger that the oscillator would function as a self-oscillating detector developing a difference frequency which would be transmitted through the grid-plate capacity of tube 4 and through intermediate frequency amplifier 16.

Preferably the system is originally adjusted so that with no incoming signal the D. C. grid bias of detector 4 is such that the point of operation on the grid voltage plate current characteristic is the point where the curvature is the greatest, and furthermore so that the beating oscillator peak voltage is at least equal to the additional bias necessary to cause plate current cut off. Then when signals are received, an additional negative bias is applied to the detector grid due to the drop across resistance 11, resulting in two simultaneous effects, one a shift downwardly to

an operating point on the characteristic of detector 4 at which the curvature is less, and the other, an effective reduction of the beating oscillator input, due to an increased portion of the wave being below plate current cut off.

Then as the signaling waves incoming to the loop decrease in strength, due, for example, to fading, the D. C. plate current of detector 15 decreases and, hence, the IR drop across resistance 11 decreases, causing reduction of the negative grid bias of detector 4 and consequent shift upwardly to an operating point on the characteristic of detector 4 at which the curvature of the characteristic is greater, and also causing an increase in the effective beating oscillator input. This tends to increase the output of the high frequency detector and, therefore, counteracts the decrease in the strength of the signaling waves received by loop 3.

When the strength of the signaling waves received by the loop increases, the reverse action occurs, tending to cause a decrease in the output of the receiver.

The system thus compensates for carrier fading by automatically readjusting the receiver gain. The use of such compensation enables satisfactory reception of speech in cases in which the reception would otherwise be unsatisfactory, due to violent fading.

In the theoretical limiting case in which a change in the plate current of the second detector is just sufficient to produce in resistance 11 sufficient IR drop to cut off the plate current of the first detector, the second detector voltage input, which that second detector plate current change represents, is the greatest voltage input to which a signal of any magnitude whatever can subject the second detector, because a greater voltage input to the second detector cuts off the plate current of the first detector and thereby completely destroys the signal.

The system has a very large volume control range per tube on which the grid bias variation is effected. With a system such as shown in Fig. 1, in which the resistance 11 was 20,000 ohms and the capacity 10 was 1 mf., tests showed that an increase in signal voltage input of one million-fold only doubled the input voltage of the low frequency detector.

When the plate current of the high frequency detector approaches cutoff by the operation of the fading prevention means, the signal cannot appear in appreciable magnitude even due to passage through inter-electrode tube capacities, since detector 4 is then very inefficient in converting the incoming frequency to that frequency required by the intermediate frequency amplifier 16.

Since the tube on which the grid bias change is effected is a detector tube, the change of bias does not produce danger of singing or characteristic resonant frequency shift.

Moreover, when control is effected by varying the grid bias of amplifiers, fading causes the tube noise to bob up and down, even though the signal may be steady; whereas in the system of Fig. 1, existing tube noise is steady as well as the signal, which experience shows to be less disturbing.

In regard to the speed of operation of the control, when resistance 11 is 20,000 ohms and capacity 10 is 1 mf. the time constant RC of the control is $20{,}000\times10^{-6}=0.02=\frac{1}{50}$ second. This is sufficiently fast for practically all cases of ordinary fading. The capacity 10 should be sufficiently large to offer a low impedance path to ground for the high frequencies and particularly to prevent intermediate frequency feed-back and singing.

In order to obtain a large range of volume control, a receiver should have available large excess amplification. For example, if a signal amplitude fades, say, from its maximum to one-fiftieth of its maximum, the receiver should have available more than 50 times in excess amplification. The intermediate frequency voltage gain of the system described above may be, for example, 120,000 times at 300 kilocycles, or may be the largest amplification from which the tube noise can be tolerated.

In the system described above, the wide frequency separation between the A. C. output from tube 15 and the A. C. input to tube 4 tends to prevent singing due to the feedback from resistance 11 to the input circuit of tube 4.

Still further insurance against singing in a fading control system of this general type can be obtained by employing more than two stages of detection, and effecting the fading control by varying the bias of the grid of the first detector in response to the volume changes in the output of the last detector. The frequency of the input wave applied to the last detector will then be widely different from the frequency of the output wave of the first detector, and the danger of singing will be reduced to a greater degree than in a double detection system.

Fig. 2 illustrates, by way of example, a triple detection system, when the switch 20 therein is closed and the switch 21 is open. The system is then like the system of Fig. 1, except for the insertion between the first intermediate frequency amplifier 16 and the low frequency detector 15, of the detector 22 and its beating oscillator 23 and the second frequency selective intermediate frequency amplifier 24. Since danger of intermediate frequency singing is considerably reduced, compared with a double detection system, the capacity of condenser 10 may be greatly reduced, with consequent reduction in the time

constant of the system and with resulting improvement in the operating speed of the fading control.

Where it is desired to reduce the range of variation which the signals produce in the input to the third detector, the bias of the grids of both the first and the second detector may be caused to vary, simultaneously, in response to volume changes in the output of the third detector. This control may be caused to take place by opening switch 20 and closing switch 21.

The term "low frequency" as used herein includes the limiting frequency zero, that is, D. C.

What is claimed is:

1. A receiver for speech modulated high frequency carrier waves, comprising a frequency changing unit including an electric space discharge modulating device, a source of voltage of frequency different from said high frequency and connected to said electric space discharge device for beating down said higher frequency, means for selectively amplifying the wave of changed frequency to the exclusion of said waves of high frequency, and means for detecting said selected wave to produce speech currents, said last mentioned means comprising a connection to the first detector to apply thereto a voltage of such magnitude and direction as to tend to control the volume fluctuations in said speech currents due to fluctuations in the strength of said high frequency waves.

2. A receiver for high frequency waves comprising a detector for changing the frequency of the received wave, means for amplifying the wave of changed frequency, a second frequency changing detector, a second means for amplifying the wave of reduced frequency delivered by said second detector, and means for detecting the amplified wave from said second amplifying means, said last mentioned means comprising a vacuum tube device with a connection to the first detector to apply thereto a potential of such magnitude and direction as to tend to maintain constant the output of the receiver.

3. A receiver for high frequency waves comprising a detector for changing the frequency of the received wave, means for amplifying the wave of changed frequency, a second frequency changing detector, a second amplifying means for amplifying the wave of reduced frequency delivery by said second detector, and means for detecting the amplified wave from said second amplifying means, said last mentioned means comprising a vacuum tube device with a connection to the first detector and a connection to the second detector to apply to said detectors potentials of such magnitude and direction as to tend to maintain constant the output of the receiver.

4. A receiver for high frequency waves comprising a plurality of frequency changing detectors, an amplifier, for each of the waves produced by said frequency changing detectors, means for detecting the lowest changed frequency wave to produce signal currents, and means energized by said signal currents to apply to the first detector, a variable potential of such magnitude and direction as to tend to maintain the signal volume constant.

5. A system for converting alternating current into uni-directional current comprising space discharge devices including a plurality of rectifiers for supplying current to a load circuit, impedance elements and sources of biasing potential individual to said space discharge devices, and coupling means interconnecting said devices, said impedance elements and coupling means being current responsive to vary the conversion efficiencies of said rectifiers in accordance with fluctuations in the alternating current.

6. A wave detecting system controlled in respect to detection efficiency by means of and in accordance with selected characteristics of the waves to be detected, comprising a plurality of space discharge devices, an input circuit for supplying waves to said devices, individual means for biasing each of said devices, an output circuit for transmitting detected currents to a load circuit, and means for utilizing a portion of said detected currents for varying the biasing potential applied to a plurality of said devices.

7. A receiver of high frequency energy comprising means for reducing the frequency of the received energy, means for producing a uni-directional current from the reduced frequency energy, and means controlled by said uni-directional current for applying a variable potential to said frequency reducing means to control its operation.

8. A radio receiver comprising means for changing the frequency of the received wave, means for producing a uni-directional current from the wave of changed frequency, and means supplied with said uni-directional current for controlling the operation of said frequency changing means in accordance with a variable characteristic of said received wave.

9. A radio receiver comprising means for changing the frequency of the received wave, means for producing a uni-directional current from the wave of changed frequency, and means supplied with said uni-directional current to control the operation of said frequency changing means to maintain constant the current output of said receiver in spite of variations in said received wave.

10. In a system for receiving waves of given frequency including a space discharge device, means to apply waves of said given frequency to the control electrode of said device, means for changing the frequency of the waves in the output circuit of said system to

a different frequency level, means to derive from said waves of changed frequency a negative voltage, and connections for applying said negative voltage to the control electrode of said discharge device to vary the gain of said system, said system including means preventing the application to said control electrode of wave components having the same frequency level as the received wave.

11. In a wave receiving system comprising a plurality of space discharge devices, means to impress waves of the received frequency on certain of said devices, an amplification control comprising means for impressing upon the control electrode of certain of said devices a potential, which becomes more negative with increasing output and less negative with decreasing output, whereby said output is maintained substantially constant with varying input and means to avoid singing in said system, due to feed back, comprising frequency changing means producing a wave from which said negative potential is exclusively derived and which differs in frequency by a large amount from the received frequency.

In witness whereof, I hereunto subscribe my name, this 23rd day of December, A. D., 1926.

EDMOND BRUCE.

June 13, 1933. D. T. SIMONDS 1,914,219

SIGNALING SYSTEM

Filed Jan. 3, 1927

Fig.1.

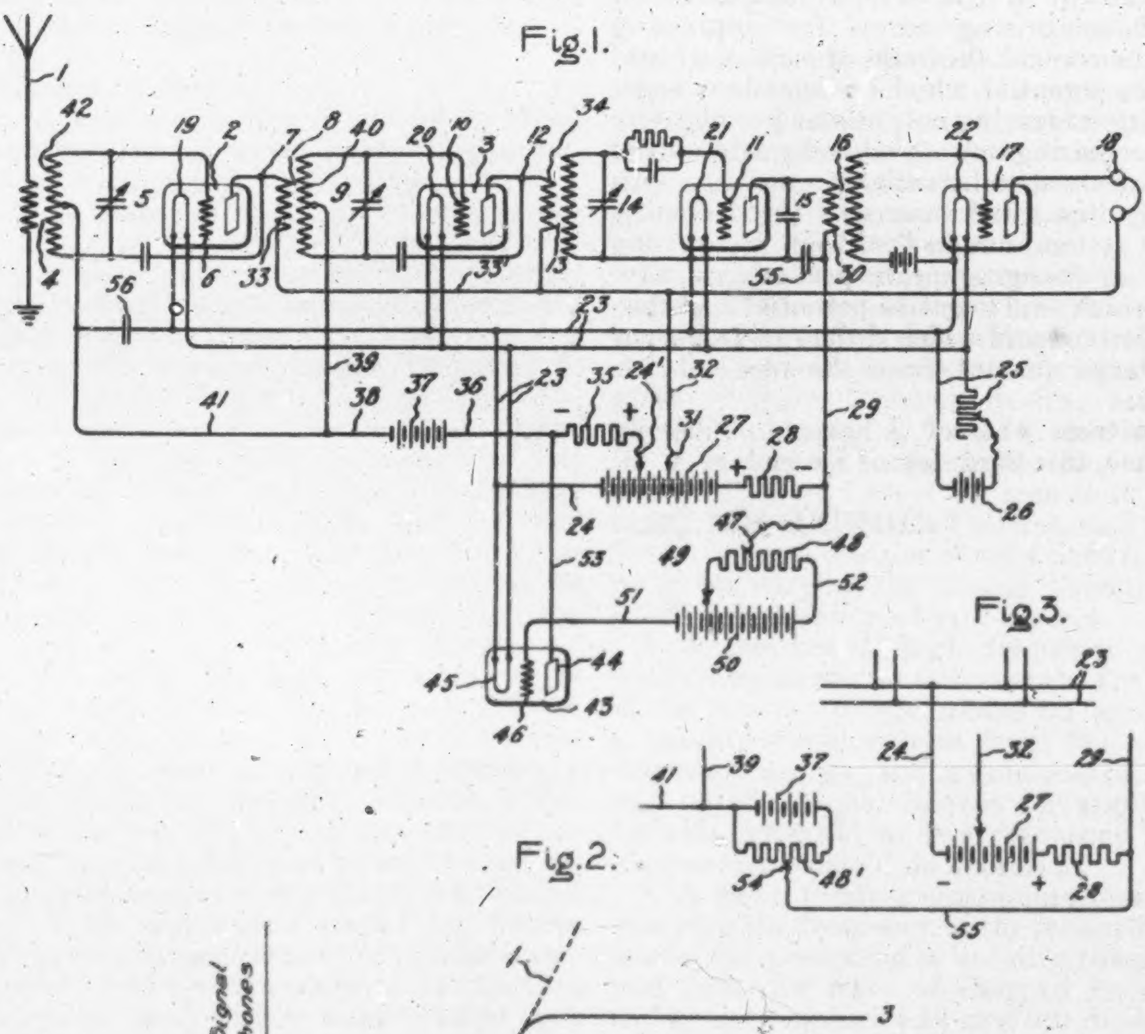


Fig.3.

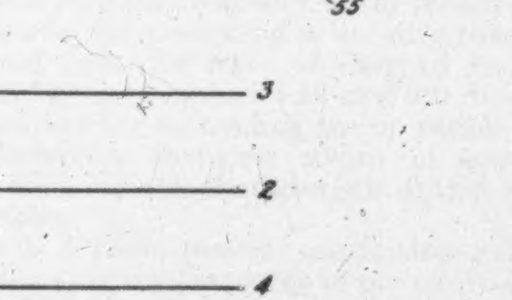
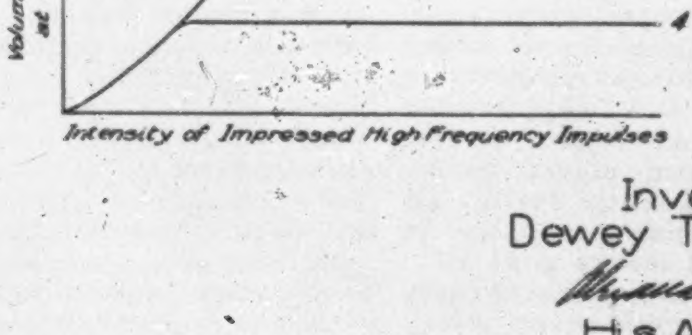


Fig.2.



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Dewey T. Simonds.

His Attorney.

Patented June 13, 1933 1,914,219

UNITED STATES PATENT OFFICE

DEWEY T. SIMONDS, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK

SIGNALING SYSTEM

Application filed January 3, 1927. Serial No. 158,454.

My invention relates to signaling systems and particularly to systems for the reception of high frequency signaling currents, and has for its purpose to provide a signaling system such that the intensity of the received signal will be automatically maintained at or below a predetermined level.

It is well known that when the receiving circuits of a high frequency signaling system have been adjusted to produce great enough amplification for reception of signals from a distant station the signals from a near by station will be received in much greater volume than is desired. Likewise, it may result that during reception from a single station the transmission characteristics of the media over which the signals are being transmitted may vary causing the intensity of the received signals to fluctuate thereby necessitating frequent readjustment of the receiving circuit to compensate for the variations in the transmission media and to maintain the desired volume level of the received signal.

Means have heretofore been provided for automatically controlling the transmission level in high frequency systems. These means have usually involved relays which operate responsively to the intensity of the received high frequency impulses to control the power circuit to a motor which affects appropriate adjustments in the transmission circuit. Others have involved relays which operate responsively to the intensity of pilot frequencies transmitted over the same transmission media as the signal, while still others have involved relays which operate responsively to changes in current passed through pilot wires which are subjected to the same transmission conditions as the media over which the desired signal is bein gtransmitted. Still other means have been provided for manually controlling the transmission level.

All of these systems have inherent disadvantages in that they either require the presence of a skilled operator or are complicated in their circuit construction necessitating the use of auxiliary carrier current generators, pilot wires and the like. Furthermore, the use of relays, motors and other instrumentalities having moving parts introduce disturbances and time delay in the operation of the system which in turn result in undesirable effects upon the receiver.

The purpose of my invention is to provide an apparatus of the type mentioned, which will be entirely automatic in its operation; and which will be simple in its circuit construction and entirely electrical in its operation. By the provision of such an apparatus I have found that the disadvantage of previous apparatus referred to above may be largely eliminated.

By my invention I vary the degree of amplification of the signaling circuit in direct electrical response to the intensity of the high frequency impulses which are impressed upon the system.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation will best be understood by reference to the following description taken in connection with the accompanying drawing, in which Fig. 1 illustrates diagrammatically one form of my invention; Fig. 2 presents curves illustrating its operation; and in which Fig. 3 illustrates a modification of the circuit shown in Fig. 1.

With reference to Fig. 1, 1 illustrates a circuit leading to the usual antenna or wire line depending upon the particular application for which the system is employed. 2 and 3 represent the usual radio frequency amplifiers of the receiving circuit, amplifier 2 being supplied with energy from the input transformer 4 and input circuit 5 which is connected to the control electrode or grid 6 of the amplifier 2. Likewise, energy is supplied from the output circuit 7 of the electron discharge device 2 through the transformer 8, and tuned circuit 9 to the control electrode or grid 10 of the amplifier 3. 11 represents the detector of the usual receiving circuit. This detector receives its energy from the output circuit 12 of the amplifier 3 through the transformer 13 and input circuit 14. Audio frequency currents from the detector are supplied from the output circuit 15 through

transformer 16 to the audio amplifier 17 where they are amplified and impressed upon the head phones 18. While the amplifiers 2 and 3 and the detector 11 are shown as of the electron discharge type, it will be apparent that any type of amplifier or detector may be used. Since the circuit connections of the amplifiers and detector, as thus far described are merely those of a common receiving circuit, only so much detail is given as is necessary to an understanding of my invention. The cathodes 19, 20, 21 and 22 of the radio amplifiers 2 and 3, detector 11 and audio amplifier 17 are shown connected to a circuit 23 which is energized through resistance 25 from a suitable source of potential 26. Suitable high potential is supplied to the output circuit of the detector 11 from the high potential source 27 through a circuit as follows: cathode 21, cathode conductors 23, conductor 24, source of potential 27, resistance 28, conductor 29, primary winding 30 of the transformer 16 to the anode of the detector 11. The source of potential 27 which comprises the usual B battery of a receiving circuit is provided with an adjustable tap 31 from which a suitable potential may be supplied through conductor 32 and conductor 33′ to the anode of the amplifier 2 through the primary winding 33 of the transformer 8, to the anode of the amplifier 3 through the primary winding 34 of the transformer 13 and to the anode of the amplifier 17 through the head phones 18. Likewise, a suitable source of potential is impressed upon the control circuits of the amplifiers 2 and 3 with respect to their cathodes 19 and 20 through a circuit as follows: cathode conductors 23, conductor 24, that portion of the source of potential 27 which is between the conductor 24 and the adjustable tap 24′, adjustable tap 24′, resistance 35, conductor 36, source of potential 37, conductor 38, thence through conductor 39, and a portion 40 of the secondary winding of the transformer 8 to the control electrode 10 of the amplifier 3, and through the conductor 41 and a portion 42 of the secondary winding of the transformer 4 to the control element 6 of the amplifier 2. It will be seen that the source of potential 37 is in series with that portion of the source of potential 27 which is between the conductor 24 and the adjustable tap 24′. Hence the effective potential on the control elements 6 and 10 of the amplifiers 2 and 3 with respect to their respective cathodes will be determined by the sum of these two sources of potential and by the potential on resistance 35. This biasing potential is normally such that these devices operate principally as amplifiers, and with substantially a minimum of detecting effect.

As already explained the resistance 28 is connected in a circuit including the output circuit of the detector 11. Hence the direct current which flows in the output circuit of the detector 11 flows through the resistance 28. Since this current varies in response to the intensity of the high frequency impulses which are impressed upon the detector 11, the potential upon the resistance 28 will correspondingly vary. I utilise this potential upon the resistance 28 as a means for controlling the amplification of the radio amplifiers 2 and 3. To this end, the amplifier 43 having an anode 44, a cathode 45 and a control electrode or grid 46 is employed. A suitable source of potential is impressed upon the control electrode 46 with respect to the cathode 45 through an input circuit including the cathode 45, cathode conductors 23, conductor 24, source of potential 27, resistance 28 which constitutes a variable source of potential, conductor 29, adjustable tap 47, that portion of the resistance 48 which is between the adjustable tap 47 and adjustable tap 49, adjustable tap 49, that portion of the source of potential 50 which is between the contact 49 and conductor 51, conductor 51 to the control electrode 46. A portion of the source of potential 50 is closed circuited through the adjustable tap 49, resistance 48 and conductor 52. The purpose of this arrangement will be seen later. A suitable potential is impressed upon the anode 44 of the amplifier 43 with respect to the cathode 45 through an output circuit including the cathode 45, cathode conductors 23, conductor 24, that portion of the source of potential 27 which is between the conductor 24 and the adjustable tap 24′, adjustable tap 24′, resistance 35, conductor 53 to the anode 44.

For the purpose of preventing alternating current from being supplied from the output of detector 11 to the input of the amplifiers 2 and 3 through the volume control circuits the condenser 55 is inserted between the conductor 29 and the cathode conductors 23 and condenser 56 between the conductor 41 and cathode conductor 23.

The operation of the circuit is as follows: During normal operation when the volume of the received signal is at or below a predetermined level, current will be flowing in the anode circuit of the detector 11 and through the resistance 28. The sum of the potentials in the control circuit of the amplifier 43 which includes the source of potential 27, resistance 28, a portion of resistance 48, and that portion of the source of potential 50 which is between the adjustable contact 49 and the conductor 51 will be such that a strong negative potential will be impressed upon the electrode 46. This being the case, no current will flow in the anode circuit of the amplifier 43 and as a result no voltage will appear upon the resistance 35. The sum of the potential 37 and that portion of the source of potential 27, which is between the adjustable contact 24′ and the conductor 24, is such that the am-

plification of the amplifiers 2 and 3 will be a maximum and reception will take place in the usual way.

Now assume that a signal of higher intensity is impressed upon the receiving system. Then the voltage on the resistance 28 will diminish and the source of potential 27 will become effective upon the electrode 46 causing it to assume a less negative or even positive potential depending upon the intensity of the received high frequency impulses. Hence, current will flow in the anode circuit of the amplifier 43 and through the resistance 35 causing a voltage to appear upon this resistance having the polarity indicated in the drawing. Since this voltage is in series with the source of potential 37 in the circuit of the control elements of the amplifiers 2 and 3, the potential upon the control elements will be increased in a negative direction, thereby correspondingly diminishing the amplification of the circuit and thereby diminishing the intensity of the signals at the receiver.

This operation may best be understood by reference to Fig. 2 in which I have plotted the intensity of the high frequency impulses which are impressed upon the receiving circuit as abscissæ and the intensity of the signal at the head phones for any given percentage modulation as ordinates. The curve 1 represents the operation of the circuit when the potential upon the electrode 46 of the amplifier 43 is so strongly negative that no current flows through the anode circuit of this amplifier or through the resistance 35. Assume that it be desired to maintain the volume of the received signals at the head phones at a level indicated by the curve 2. The contacts 47 and 49 will be adjusted to impress a negative potential on the control electrode 46 such that no current will flow through the resistance 35 until the high frequency impulses impressed upon the detector are of such volume as to produce a signal at the head phones corresponding to the level represented by the curve 2 at the given percentage modulation. Then for all high frequency intensities which produce signals below this level the amplification of the circuit will be at a maximum and reception will take place on the curve 1. If the volume of the high frequency impulses which are impressed upon the detector 11 become so great as to cause the volume of the received signal at the head phones to exceed the level represented by the curve 2 then the negative potential on the electrode 46 will be so diminished that current will flow through the anode circuit of the amplifier 43, causing a diminution in the amplificaiton of the amplifiers 2 and 3. Hence, all high frequency impulses which produce signal intensities above the level 2 at the given modulation will be diminished to this level, whereas, intensities below this volume level will be unaffected. If it be desired to increase the volume level of the received signal, then the contacts 47 and 49 may be so adjusted that a stronger negative potential will be impressed upon the grid 46. With such an adjustment a greater volume must be impressed upon the resistance 28 before the negative potential on the electrode 46 will be sufficiently diminished to permit the flow of current through the anode circuit of the amplifier 43. Hence, only intensities above those represented by the curve 3 will be diminished and reception will take place on the curve 3. By adjusting either of the contacts 47 or 49 in the opposite direction reception can be made to take place upon the cirve 4.

With the potentiometer contact 47 adjusted to impress any desired bias on the grid of the direct current amplifier, current starts to build up in the anode circit of the amplifier at a corresponding critical value of input radio frequency voltage to the detector. As the radio frequency input voltage to the detector increases beyond this critical value the current in the direct current amplifier increases extremely rapidly, and in a substantially linear relation to the radio frequency input voltage. In this way sufficient control of the amplification is had to maintain the volume of signal at the headphones within a satisfactorily small range of variations in intensity.

In Fig. 3 of the drawing I have shown a modification of my invention in which the amplifier 46 has been omitted. It will be seen that in this case conductors 39 and 41 are connected through the source of potential 37 and the resistance 48′, which have been connected in parallel relation for purposes of adjustment, adjustable contact 54 and conductor 55 to the point on the resistance 28, which is connected to the output circuit of the detector 11. Hence, it will be seen that any fluctuations in the potential of the resistance 28 will be impressed directly upon the control circuits of the amplifiers 2 and 3. An arrangement of this type may be preferable in a circuit where only small adjustments are required as where the changes in the characteristics of the transmission media are small, or in a circuit where a number of amplifiers are used, such that the adjustment is effective upon a number of amplifiers. This arrangement effects a substantial economy in the apparatus required.

While I have described my invention with particular reference to a common receiving circuit employing a particular type of detector it will be apparent that it is not so limited but rather that it may be employed in almost any type of high frequency receiving system where a contact volume of output is desired. Likewise, in the embodiment shown I have employed a detector as the controlling tube purely from considerations of economy in the

apparatus since, obviously, any type of rectifying device may be employed as well.

Furthermore, it will be apparent that the control device may be made to operate upon amplifiers subsequent in the circuit to the controlling tube 11 rather than prior to it as in the embodiment shown and that such an arrangement will have certain advantages such as results from the fact that it entirely eliminates regeneration or any tendency to oscillate. This also enables me to make condensers 55 and 56 of very small capacity, thereby eliminating any time delay in the operation of the device which may be produced by the charging of these condensers. However, I have found that with this arrangement greater difficulty is encountered in obtaining substantially horizontal characteristics as shown in Fig. 2 over a large range of intensities of impressed high frequency impulses, than is the case in the embodiment shown.

It may thus be seen that I have provided a volume control device which is simple in its circuit structure and its operation and which does not require the attention of a skilled operator, which operates directly in response to the high frequency impulses which are impressed upon the circuit rather than in response to changes in a pilot frequency which is transmitted over the same media as the received signal, or in response to current flowing in pilot wires, which are subjected to the same conditions as the media over which the received signal is transmitted, as has been done heretofore. My invention has the further advantage that it is completely electrical in its operation and does not involve any mechanical moving parts, such as motors, relays and the like, which introduce undesirable effects in the operation of the system. Hence my device is practically instantaneous in its operation. My invention has a further advantage in that it involves but a small amount of apparatus and that it may be applied with facility and without great expense to any of the usual signaling circuits.

While I have shown and described a specific embodiment of my invention, it will be apparent that it is not limited to the particular embodiment shown but that many modifications in the circuit arrangements and instrumentalities employed in carrying out my invention may be made without departing from the scope thereof as set forth in the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is:—

1. The combination in a receiving circuit employing an electron discharge amplifier having a control element, a detector and connections whereby current having amplitude dependent upon the characteristics of the transmission medium are supplied to said amplifier and detector, a resistance connected in the output circuit of said detector, an electron discharge device having an anode, a cathode and a grid, said resistance being connected between said cathode and said grid, a second resistance connected between the anode and cathode whereby the potential on said second resistance is dependent upon the output current of said detector and means for varying the potential on said control element in response to the potential on said second resistance thereby to control the amplification of said amplifier.

2. The combination, in a receiving circuit embodying an electron discharge amplifier having a control element, connections whereby current having amplitude dependent upon the characteristics of the transmission medium over which currents are received are supplied to said amplifier, means for rectifying a portion of said current thereby to produce a source of direct current potential which is variable in response to the intensity of the received current, means for amplifying said direct current potential and for supplying the amplified potential to the control element of said amplifier thereby to control the amplification in response to the intensity of the received current.

3. The combination in a signaling system, employing an electron discharge device having a grid, means for impressing a biasing potential on said grid such that said device operates principally as an amplifier and with a minimum of detecting effect, means for supplying current to be amplified to said grid, a second electron discharge device having an anode circuit, a cathode and a grid, means for impressing a uni-directional biasing potential on the grid of said second device such that substantially no current normally flows in the anode circuit thereof, means for varying said uni-directional biasing potential on the grid of said second device in response to the intensity of the received current and to cause current to flow in the anode circuit thereof when the intensity of received current exceeds a predetermined value and means for controlling the potential on the grid of said first device in response to the current in this anode circuit of said second device thereby to regulate the amplification of said first device.

4. In a high frequency receiving system, sound reproducing means, an electron discharge device having a grid, means for impressing high frequency potential on said grid, means for impressing a biasing potential on said grid such that said device operates principally as an amplifier of said high frequency current and with a minimum of detecting effect, additional means comprising an electron discharge detector for deriving audio frequency current from the amplified high frequency current and for supplying said current from said detector to the sound

reproducing means, and means including said detector for varying the direct current potential upon the grid of said first mentioned electron discharge device only when the high frequency input to said detector exceeds a predetermined value and then to vary said direct current potential substantially linearly with respect to variation in said high frequency input to said detector thereby to control the amplification of said electron discharge device.

5. In the operation of a carrier wave receiver of the type including a carrier wave amplifier, a detector and an audio frequency output circuit fed from said detector, the method of automatically reducing the effects of varying signal strength which comprises amplifying the direct current potential developed in the plate circuit of the detector, and impressing the amplified direct current potential upon said carrier wave amplifier to control the amplification thereof.

6. In a carrier wave receiver, the combination with a carrier wave amplifier, a detector and an audio frequency output circuit fed from said detector, of an impedance in the plate circuit of said detector, a direct current amplifier connected across said impedance, and circuit connections for impressing the amplified output of said direct current amplifier upon the carrier wave amplifier to control the amplification thereof.

7. A carrier wave amplifier of the vacuum tube type and including circuit elements for automatically impressing upon said amplifier an amplification-control voltage proportional to received signal strength, characterized by the fact that said circuit elements include a direct current amplifier.

8. In combination, an audion, an output circuit therefor, means for suppressing fluctuations in said output circiut due to variations in the strength of an incoming signal, said means comprising a rectifying system having a critical input voltage below which substantially no direct-current output is obtained, and means for adjusting said critical voltage.

9. In an electrical system, the combination with an audion having input and output circuits, of means for suppressing fluctuations in said output circuit due to variations in the strength of an incoming signal in said input circuit, said means comprising a rectifying system of the type having an approximately linear relation between direct-current output and radio frequency input above a critical input voltage, and means for varying the critical voltage of said rectifying system.

10. In an electrical system, the combination with an audion, of means energized by said audion for impressing a variable bias on said audion, said means having a critical working voltage, and means for adjusting said critical voltage.

11. The combination with an audion, of means for biasing said audion by a direct-current voltage, means for automatically varying said bias voltage in accordance with the strength of an incoming signal, at least one of said means comprising a rectifying system including an element having a critical working voltage, and means whereby said critical voltage may be adjusted.

12. In combination, an audion, an output circuit therefor, means for suppressing fluctuations in said output circuit due to variations in the strength of an incoming signal, said means comprising a rectifying system having a certain input voltage below which substantially no direct current output is obtained and above which said direct current output rapidly rises and attains an approximately linear relation with respect to the intensity of the signal applied to the input of said detector, and means for adjusting said certain input voltage.

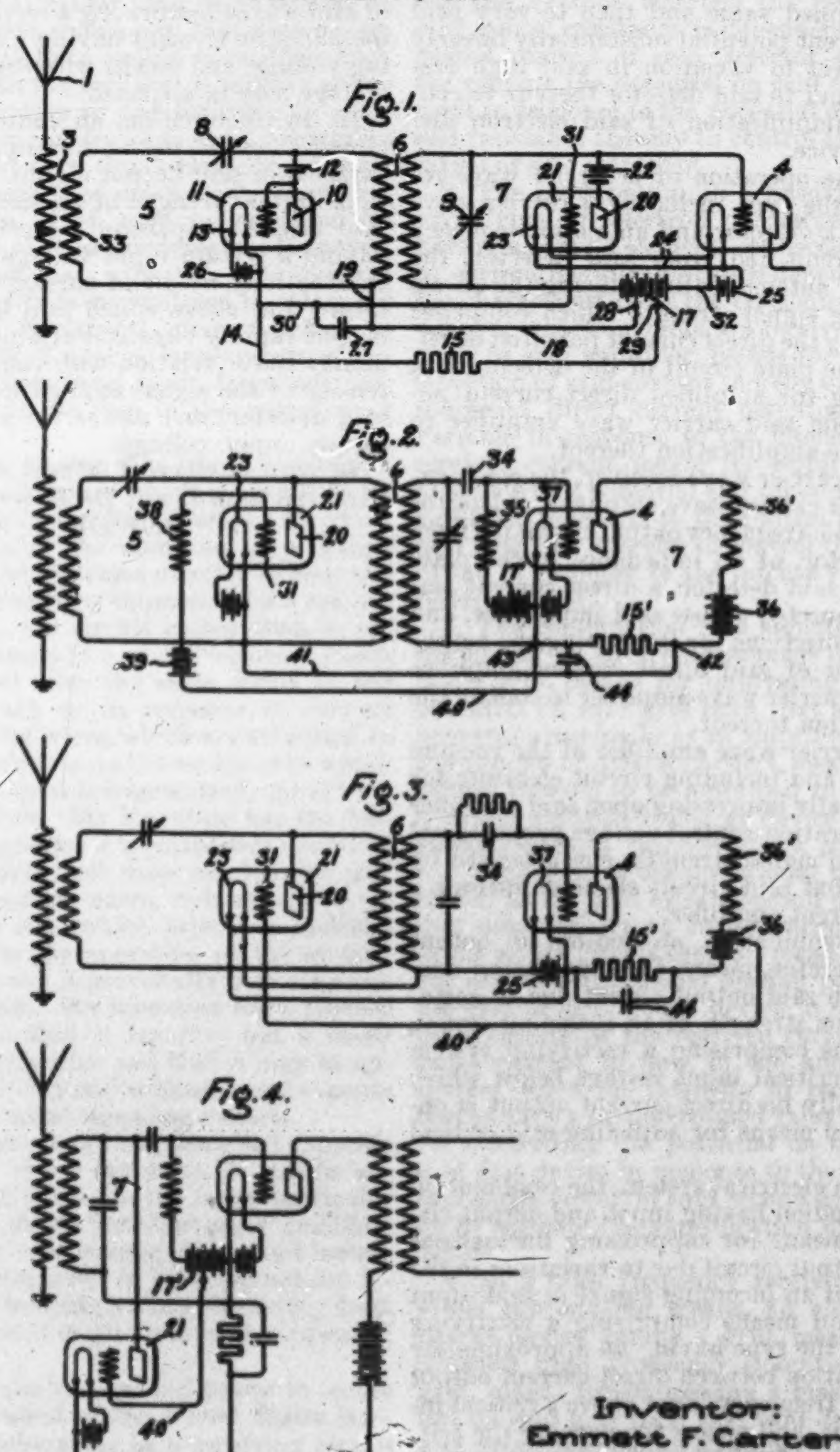
In witness whereof, I have hereto set my hand this 31st day of December, 1926.

DEWEY T. SIMONDS.

Dec. 10, 1929. E. F. CARTER 1,739,351

HIGH FREQUENCY SIGNALING SYSTEM

Filed Jan. 14, 1927



Inventor:
Emmett F. Carter,
by [signature]
His Attorney.

Patented Dec. 10, 1929 1,739,351

UNITED STATES PATENT OFFICE

EMMETT F. CARTER, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK

HIGH-FREQUENCY SIGNALING SYSTEM

Application filed January 14, 1927. Serial No. 161,188.

My invention relates to signaling systems and particularly to systems employing high frequency currents, and has for its purpose to provide a signaling system such that the intensity of the received signal will be automatically maintained at or below a predetermined level.

It is well-known, that when the receiving circuits of a high frequency signaling system have been adjusted for reception of signals from a distant station the signals from a near by station will be received in such great volume that they cannot be understood and may cause discomfort for the operator who is listening at the head phones. Likewise, it may result that during reception from a single station the transmission characteristics of the media over which the signals are being transmitted may vary causing the intensity of the received signals to fluctuate, thereby necessitating frequent readjustment of the receiving circuit to compensate for the variations in the transmission media and to maintain a desired volume level of the received signal.

Means have heretofore been provided for controlling the transmission level in high frequency systems. These means have usually involved relays which operate responsively to the intensity of the received high frequency impulses to control the power circuit to a motor which affects appropriate adjustments in the transmission circuit. Others have involved relays which operate responsively to the intensity of pilot frequencies transmitted over the same transmission media as the signal, while still others have involved relays which operate responsively to changes in current passed through pilot wires which are subjected to the same transmission conditions as the media over which the desired signal is being transmitted. Still other means have been provided for manually controlling the transmission level.

All of these systems have inherent disadvantages in that they either require the presence of a skilled operator or are complicated in their circuit construction necessitating the use of auxiliary carrier current generators, pilot wires and the like. Furthermore, the use of relays, motors and other instrumentalities having moving parts introduces disturbances and time delay in the operation of the system which in turn result in undesirable effects upon the receiver.

The purpose of my invention is to provide an apparatus of the type mentioned which will be entirely automatic in its operation; and which will be simple in its circuit construction and entirely electrical in its operation. By the provision of such an apparatus I have found that the disadvantage of previous apparatus referred to above may be largely eliminated.

By my invention I propose to employ an impedance connected in shunt relation to a tuned portion of the signaling circuit which impedance I propose to vary in response to the intensity of the impressed carrier currents to detune the tuned circuit and to shunt off a portion of the signal. For this impedance I prefer to employ an electron discharge device since the well-known characteristics of such devices are such that their impedance may be varied over a very wide range in response to a small variation in the electrical condition of the control element of the device.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation will best be understood by reference to the following description taken in connection with the accompanying drawings in which Fig. 1 illustrates diagrammatically one form of my invention; Fig. 2 illustrates my invention applied to a circuit including a grid bias detector; Fig. 3 illustrates my invention applied to a circuit including a grid leak detector, and Fig. 4 shows a modification of the circuit shown in Fig. 2.

Referring first to Fig. 1, 1 indicates an antenna, if the invention be applied to radio reception, or a wire circuit if the invention be employed in carrier current reception. 3 indicates the coupling transformer for inductively connecting the transmitting circuit and the receiving circuit with the antenna

or the wire circuit. 4 indicates a detector tube which is associated with the receiving apparatus for the purpose of detecting the received carrier signals and for transmitting them to the operator's receivers or head phones. Signals are transmitted to this detector tube through a tuned link circuit 5, which is inductively connected by means of a transformer 6, to the tuned input circuit 7 of the detector 4. For the purpose of tuning the circuits 5 and 7 to resonate at the frequency of the signal which is to be received, condenser 8 in the link circuit 5 and a condenser 9 in the circuit 7 is provided. To one side of the tuned link circuit 5 is connected the anode 10 of the electron discharge device 11 through a suitable source of potential 12. With the other side of the tuned link circuit 5 is associated the cathode 13 of the electron discharge device through a circuit comprising the conductor 14, resistance 15, part of battery 17, conductor 18, and conductor 19. With the one side of the circuit 7 is associated the anode 20 of the electron discharge device 21 through a suitable source of potential 22. The cathode 23 of the electron discharge device 21, is connected to the opposite side of the tuned circuit 7 through conductors 24, and the grid 31 of the electron discharge device 21 is connected through the conductor 30 to the cathode 13, of electron discharge device 11. A suitable by-pass condenser 27 is provided between the cathode 13 and the conductor 19 for the purpose of shunting the alternating currents out of the resistance 15 and the battery 17. A suitable source of potential 25 is provided for heating the cathodes of electron discharge device 21, and of the detector 4. A similar source of potential 26 is provided for heating the cathode of the electron discharge device 11.

The operation of this form of my invention is as follows. During normal operation of the circuit when the volume of the received high frequency impulses is below a certain predetermined level and reception is taking place through the detector 4 in the usual way, the electron discharge device 11 will be inactive. This is because the source of potential 12, which is in series with that portion of the battery 17 which is between the contacts 28 and 29 through a circuit including the primary winding of the transformer 6, conductor 19, conductor 18, contact 28, battery 17, contact 29, resistance 15, conductor 14 and cathode 13, establishes a negative potential upon the anode 10 with respect to the cathode 13, such that no passage of electrons from the cathode to the anode and no flow of current in this circuit can take place. The anode of the electron discharge device 21 is similarly biased by means of the battery 22 and the battery 17 through a circuit including the secondary winding of the transformer 6, but this bias is not so great but that a flow of electrons from the cathode 23 to the anode 20 will take place except when the grid 31 is biased negatively with respect to the cathode 23. This bias is effected by means of that portion of the battery 17 which is between the cathode connection 32 and the contact 29 through a circuit including the resistance 15, conductor 14, conductor 30 to the grid 31.

Assuming that a change in the transmission characteristics of the media over which the signal is being transmitted has occurred, or that suddenly a nearby station for which the receiving circuit has not been adjusted starts to transmit, or that for some other cause the intensity of the high frequency impulses, which are impressed upon the receiving circuit increases a larger voltage will then be impressed upon the winding 33 of the coupling transformer 3. This voltage will overcome the negative potential of the anode 10 and a passage of electrons from the cathode 13 to the anode 10 will take place. Hence current will flow through the circuit including the cathode 13, conductor 14, resistance 15, contact 29, that portion of the battery 17, which is between the contact 29 and contact 28, contact 28, conductor 18, conductor 19, primary winding of the transformer 6, battery 12, anode 10 and thence through the space between the anode 10 and the cathode 13 back to the cathode. Thus a potential will be set up across resistance 15 which is opposed to and greater than that portion of the battery 17 which is between the cathode connection 32 and the contact 29 and the potential of the grid 31 will be correspondingly increased in the positive direction. The circuit through which this is effected has already been traced from the grid 31 through the conductor 30, conductor 14, resistance 15, contact 29, that portion of the battery which is between the contact 29 and the cathode connection 32, back to the cathode connectoin 32. This being the case current will flow from the anode 20 to the cathode 23 through the conductors 24, battery 17, secondary winding of transformer 6, battery 22 back to the anode 20. The electron discharge device 21 will then constitute a comparatively low resistance shunt across the tuned circuit 7. The value of this resistance will depend upon the voltage across the resistance 15 which, in turn, varies with the received signal. This shunt will not only detune the circuit 7 but acting through the transformer 6 it will detune the link circuit 5 so that the resonance frequency of the circuit will no longer be the frequency of the received signal. This being the case, the efficiency of transmission of energy through the circuit will be greatly decreased and the volume of the received signal at the receiver will be diminished. When this condition of high

intensity impulses has passed, current will no longer flow through the electron discharge device 11 or the resistance 15, and the grid 31 of the electron discharge device 21 will again assume its normal negative potential and the shunt circuit through the electron discharge device 21 will no longer exist. Transmission through the circuit will again take place at the normal efficiency of the circuit. Hence, it appears that the electron discharge device 11 operates as a relay for opening and closing the shunt circuit across the tuned circuit 7 responsively to the increase or decrease of volume of the impressed high frequency impulses.

In Fig. 2, I have shown another and what I believe to be a better form of my invention, in which I only employ one tube, in addition to those of the usual receiving circuit and cause this tube to operate responsively to the direct current flowing in the anode circuit of the detector 4. The circuits employed are substantially the same as those employed in Fig. 1, with the exception that the electron discharge device 21 has been connected in shunt relation to the tuned link circuit 5 and the source of direct current potential for controlling the electron discharge device 21 is derived from the anode circuit of the detector 4, rather than from the series circuit of an electron discharge device such as 11 in Fig. 1. In this figure I have shown a circuit including a grid bias detector. High frequency signals are impressed upon the grid of the detector by means of the condenser 34 connected in the input circuit 7. The grid of the detector is supplied with a negative bias by means of the battery 17′ through a resistance 35. The anode of the detector 4 has a high positive direct current potential impressed by means of the battery 36 through the impedance 36′. Impedance 36′ may represent that of the receiver or that of the primary of an audio transformer leading to appropriate circuits which may be associated with the receiver. Connected in series with the circuit of the anode 4 is a resistance 15′ which corresponds to the resistance 15 of Fig. 1. The grid 31 of the electron discharge device 21 is connected through a circuit including the resitance 38, negative bias battery 39 and conductor 40 to the negative side of the cathode 37 of detector 4. The cathode of the electron discharge device 21 is connected through a conductor 41 to a point 42 in the anode circuit which is on the opposite side of the resistance 15′ from the cathode connection 43. With this connection it is seen that the resistance 15′ serves as a source of direct current potential for determining the bias upon the grid 31 of the electron discharge device 21. I have provided the condenser 44 between the conductor 41 and the cathode connection 43 to serve as a by-pass for the alternating currents around the resistance 15′.

The operation of this form of my invention is as follows: During normal operation of the circuit when the intensity of the received signals is below the predetermined value, the grid 31 of the electron discharge device 21 will be biased negatively with respect to the cathode 23 by the battery 39 and no current will flow from the anode 20 to the cathode 23.

Assuming that the intensity of the received signal increases and becomes greater than the predetermined value, due to an increase in the amplitude of the high frequency impulses, then the direct current flowing in the plate circuit of the detector will correspondingly increase causing an increase of direct current potential across the resistance 15′. This potential is in series with but opposed to the grid bias battery 39 through a circuit as follows: cathode 23, conductor 41, cathode connection 42, resistance 15′, cathode connection 43, conductor 40, grid bias battery 39, resistance 38 to the grid 31. Hence, upon an increase of potential across the resistance 15′, the negative bias upon the grid 31, due to the battery 39, will be overcome by the potential across the resistance 15′ and the grid will assume a positive potential. Current will then flow from the anode 20 to the cathode 23, and the electron discharge device 21 will become a comparatively low resistance shunt across the primary of transformer 6, thereby detuning this transformer and its associated tuned circuits and greatly lessening the efficiency of transmission through the circuit. This in turn will decrease the volume of received signal at the head phones.

In Fig. 3 I have shown another form of my invention as applied to a grid leak detector. It is well-known that in detectors of this type direct current flowing in the anode circuit will decrease as the volume of the impressed high frequency impulses increases rather than increase as is the case with the grid bias detector. Hence, some slight modifications of my circuit are necessary to adapt my invention to a circuit employing this type of detector. In this case the anode circuit of the detector 4 is provided with the usual battery 36 and with resistance 15′, one side of which is connected to one side of the filament battery 25, just as is done in Fig. 2. Instead of providing a separate negative bias battery for the grid 31 of the electron discharge device 21, this grid is connected through the conductor 40 directly to a low voltage tap on the anode battery 36. It is to be understood, however, that a negative bias battery may be inserted in this circuit if desired. In this case the cathode 23 of the electron discharge device 21 is connected in parallel with the cathode 37 of the detector 4, thereby eliminating the necessity for an additional cathode battery.

The operation of this form of my invention is as follows: During the normal condition of reception a direct current will be flowing in the anode circuit of the detector 4 and there will be considerable direct current voltage across the resistance 15′ having the polarity indicated in the drawing. This polarity will be opposed to and greater than that of that portion of the battery 36 which is tapped off by the grid lead 40 and a negative potential will exist upon the grid 31 of the electron discharge device 21. Assuming that the amplitude of the impressed high frequency current increases for some cause, thereby causing the signal intensity at the receiver to become greater than the predetermined value, then the direct current flowing in the anode circuit of the detector 4 will correspondingly diminish causing a drop in the voltage across the resistance 15′. This being true the potential of that portion of the battery 36, which is tapped off by the grid lead 40 will become effective upon the grid 31, and cause the grid to assume a positive potential. Current will then flow from the anode 20 to the cathode 23 and the electron discharge device 21 will become a comparatively low resistance shunt across the primary of the transformer 6, thereby detuning the transformer and its associated tuned circuits. This being the case, the efficiency of transmission through the circuit will be greatly diminished and the volume of signal received at the head phones will be decreased.

In Fig. 4 I have shown a modification of that form of my invention which is shown in Fig. 2. The circuit is the same as that shown in Fig. 2 with the exception that the control electron discharge device 21 has been connected across the tuned circuit 7 and the tuned link circuit 5 has been omitted. I have further modified the circuit by tapping the grid lead 40 to the negative bias battery 17′, thereby eliminating the necessity for a grid bias battery 39. In all other respects the circuit is the same. The operation of this form of my invention will be understood from the operation of Fig. 2.

It may thus be seen that I have provided a volume control device which is very simple in its circuit structure and in its operation and which does not require the attention of a skilled operator; and which operates directly in response to the received high frequency wave upon which the signal is impressed. My invention has the further advantage that it is completely electrical in its operation and does not involve any mechanical moving parts, such as motors, relays, and the like, which introduce undesirable effects into the operation of the system. Hence, my device is practically instantaneous in its operation. My invention has the further advantage; that it involves the addition of a single vacuum tube to the usual detector circuits and that it may be applied with facility and without great expense to any circuit where the usual detector and its associated tuned circuits are employed.

While I have shown and described my invention with particular reference to receiving circuits it will be apparent that it is not so limited and that it may be applied to transmitting circuits as well. It will also be apparent that my invention is not limited to the particular embodiment shown but that many modifications in the circuit arrangements and instrumentalities employed in carrying out my invention may be made without departing from the scope thereof as set forth in the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. In a receiving circuit employing a detector, a volume control device, comprising an electron discharge device having a cathode and an anode, said cathode being connected to one side of said receiving circuit and said anode being connected to the other side of said receiving circuit to form a shunt, and electrical means responsive to the direct current flowing in said detector for controlling the impedance between said cathode and said anode.

2. In a receiving circuit employing a detector, a volume control device, comprising an electron discharge device having a cathode, an anode and a grid, said cathode being connected to one side of said receiving circuit and said anode being connected to the other side of said receiving circuit to form a shunt, and electrical means responsive to the direct current flowing in said detector for varying the potential on said grid.

3. In a high frequency signaling system comprising a plurality of tuned circuits coupled to each other, a volume control device comprising an electron discharge device having an anode and a cathode, said anode being connected to one side of one of said tuned circuits, said cathode being connected to the other side of said tuned circuit and means associated with another one of said circuits for varying the resistance between said cathode and said anode responsively to the intensity of the impressed high frequency impulses.

4. In a high frequency signaling system comprising a plurality of tuned circuits coupled to each other, a volume control device comprising an electron discharge device, having an anode, a cathode and a grid, said anode being connected to one side of one of said tuned circuits and said cathode being connected to the other side of said tuned circuit and means associated with another one of said tuned circuits for varying the potential on said grid responsively to the intensity of the impressed high frequency impulses.

5. In a high frequency signaling system

comprising a plurality of tuned circuits coupled to each other, a volume control device comprising an electron discharge device having an anode, a cathode and a grid, said anode being connected to one side of one of said tuned circuits and said cathode being connected to the other side of said tuned circuit and means responsive to the intensity of the impressed high frequency impulses for controlling the potential of said grid.

6. In a signaling system comprising a plurality of tuned circuits coupled to each other, a volume control device comprising an electron discharge device associated with one of said tuned circuits having an anode, a cathode and a grid, said anode being connected to one side of said tuned circuit and said cathode being connected to the other side of said tuned circuit, a second electron discharge device associated with another one of said tuned circuits, and a resistor connected in series with the anode circuit of said second electron discharge device one side of said resistor being connected to the cathode of said first electron discharge device and the other side of said resistor being connected to the grid of said first electron discharge device.

7. In a signaling system comprising a tuned circuit, a volume control device comprising an electron discharge device associated with said tuned circuit and having an anode, a cathode and a grid, said anode being connected to one side of said tune circuit and said cathode being connected to the other side of said tuned circuit, to form a shunt, a second electron discharge device associated with said tuned circuit, a resistor in series with the anode circuit of said second electron discharge device and means for varying the potential on the grid of said first discharge device in response to the potential on said resistance.

8. In a signaling system consisting of a plurality of tuned circuits coupled to each other, a volume control device comprising a vacuum tube connected in shunt relation with one of said tuned circuits, a second vacuum tube having its input circuit associated with another of said tuned circuits, and a resistance in series with the output circuit of said second vacuum tube for controlling the impedance of said first vacuum tube and thereby detuning said tuned circuits.

9. In a signaling system consisting of a plurality of tuned circuits coupled to each other, a volume control device comprising a vacuum tube connected in shunt relation with one of said tuned circuits, a second vacuum tube having its input circuit associated with another of said tuned circuits, and means associated with said second vacuum tube for varying the impedance of said first vacuum tube to detune said tuned circuits.

10. In a signaling system including a plurality of associated tuned circuits, a volume control device comprising a normally inactive shunt associated with one of said tuned circuits and means associated with another one of said tuned circuits to vary the impedance of said shunt and detune said tuned circuit.

11. In a high frequency receiving circuit including a plurality of associated tuned circuits, a volume control device comprising a normally inactive shunt associated with one of said tuned circuits and means associated with another one of said tuned circuits to vary the impedance of said shunt and detune said tuned circuit, said means comprising a source of potential variable in response to the intensity of the received high frequency impulses.

12. In a receiving circuit comprising a plurality of associated tuned circuits a vacuum tube associated with one of said tuned circuits having a cathode, an anode and a grid, said cathode and said anode being connected in circuit relation across said tuned circuit, a detector associated with another of said tuned circuits and having an output circuit, a resistance in series with said output circuit, one side of said resistance being maintained at the potential of said cathode and the other side of said resistance being associated with said grid.

13. In a receiving circuit, a volume control device comprising a plurality of associated tuned circuits, a normally inactive shunt for one of said tuned circuits, a detector in said receiving circuit and means associated with the output circuits of said detector for rendering said shunt active.

14. In a receiving circuit, a volume control device comprising a plurality of associated tuned circuits, a vacuum tube having an anode, a cathode and a grid, the circuit of said anode and said cathode being connected in shunt relation with one of said tuned circuits, a detector in said receiving circuit having an output circuit, a resistance in series with said output circuit, one terminal of said resistance being connected to said cathode and the other terminal being associated with said grid.

15. In a high frequency receiving circuit employing a detector, a volume control device comprising means including a tuned circuit for controlling the input to said detector and electrical means responsive to the direct current flowing in said detector for controlling the tuning of said tuned circuit thereby to affect the signal output from said detector.

16. In a high frequency receiving circuit, a detector, a tuned circuit for controlling the input to said detector and means responsive to current flowing in said detector for detuning said tuned circuit in accordance with the gradations in intensity of said current over a range of variations thereof.

17. In a high frequency receiving circuit,

a detector, a tuned circuit for controlling the input to said detector, a shunt for detuning said tuned circuit, and means responsive to the received high frequency impulses for controlling said shunt in accordance with the gradations in intensity of said current over a range of variations thereof.

18. In a high frequency receiving circuit, a detector, means connected in shunt to said receiving circuit for detuning the receiving circuit to control the input to said detector and electrical means responsive to said detector for controlling said first means.

19. In combination, a high frequency receiving circuit, means including a tuned circuit for controlling the intensity of the output currents from said receiving circuit and means responsive to the intensity of the received high frequency currents for detuning said tuned circuit in accordance with the gradations in intensity of said currents over a range of variations thereof, said means including an electron discharge device connected in shunt with said tuned circuit.

In witness whereof, I have hereunto set my hand this 18th day of January, 1927.

EMMETT F. CARTER.

PLAINTIFF'S EXHIBIT NO. 13

8/19/26

MINUTES OF THE AUGUST MEETING OF THE I.R.M. ENGINEERS

Meeting was called to order at 10:15 A.M., August 19, 1926, in the office of the Independent Radio Manufacturers, Inc., 331 Madison Avenue, New York City, by the Chairman, Mr. Clement.

Mr. MacDonald stated that Mr. Binns desired the personal record of engineers of the Neutrodyne Group for publicity purposes. He requested that this data be furnished as soon as possible. Mr. Binns would be present later to further explain the proposition.

Mr. MacDonald further reported that there had been considerable work done on the Variable Ratio Coupling Transformer since Professor Hazeltine's report. This work was carried on by Mr. Wheeler. He had devised improved circuits with better performance and greater simplicity. He said that Mr. Wheeler would describe a standard form of this coil and that any variations could be discussed in detail with the laboratory.

He also reported that last summer, Mr. Wheeler had suggested an automatic volume control whose function was to keep the signal at the detector down to a certain level. This device had been called the Audiostat. A model had been prepared and was on exhibit at the laboratory. This device overcomes some of the greatest disadvantages of receivers.

Mr. Wheeler then presented a report on the Variable Ratio Coupling Transformers. He stated that he had worked to simplify the design. The simplest design uses one primary winding and one neutro winding on a tube considerably smaller than the tube on which the secondary is wound. He said that this coil should give an amplification of about eleven per stage. The general case of transformer used a primary coil tube of one inch diameter, while the secondary was wound on a three inch diameter tube. Each winding was two inches long. It is possible to effect variations in the transformer to use different size tubing. This transformer will cover the range with a tuning condenser of about one-half the size of that now used in three stage receivers.

Discussion on this device followed in which Mr. Wheeler brought out several points of interest. Ordinary shielding gives the circuits a total minimum capacity of about 60 micromicrofarads. The amplification at the long waves varied inversely as the square root of the tuning capacity. Shielding reduces the amplification obtainable about 5%.

Mr. Wheeler then described, in detail, the function and construction of the Audiostat. This device works by controlling the

amplification of the radio amplifier tubes by varying the grid bias, which in turn is controlled by the strength of the signal at the detector.

Mr. Clement reported that he was unable to obtain the A.C. tubes in time to prepare a report but that he would have it ready for the next meeting.

Mr. MacDonald and Mr. Manson brought up the subject of the proposed change in grid-anode capacity of the UX-201-A tubes resulting from a suggested improvement in construction. Everyone present agreed that an average increase in grid-anode capacity of 0.5 micromicrofarad would be permissible without causing trouble, but that an increase of 1.0 micromicrofarad would not be allowable.

Discussion on tube tolerances.

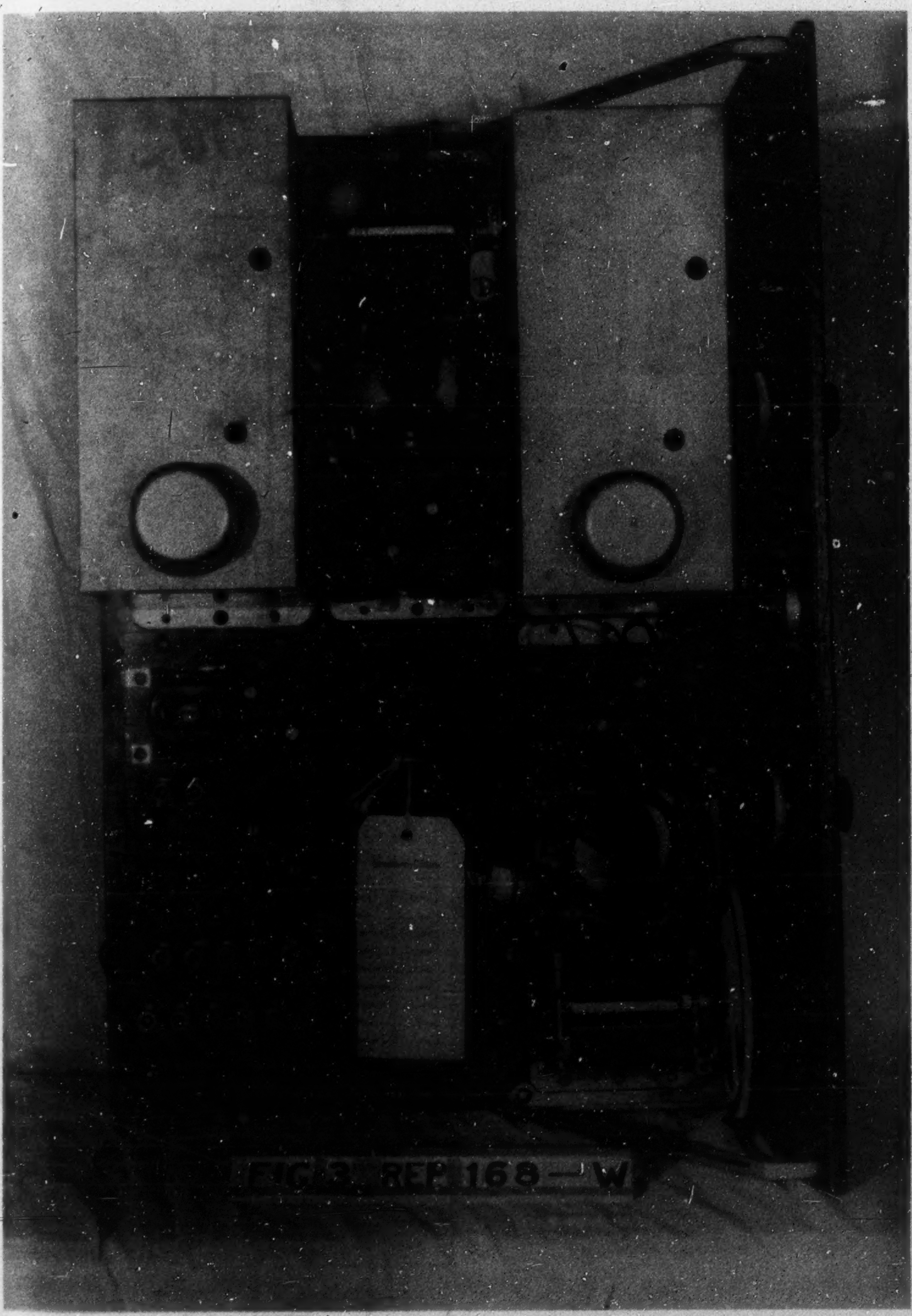
It was decided that the next meeting would be held at 10 A.M. Thursday, September 16. As this is during the Radio Show, Mr. MacDonald will report on interesting and important features of other receivers exhibited. All the members are requested to report their observation in the same lines. Mr. Clement promised the report on A.C. tubes for this meeting also.

Meeting was adjourned at 1:10 P.M.

Those present at the meeting were:

Mr. Binns - - - - - - - - - - - - - -	Hazeltine Corporation
Mr. Clement - - - - - - - - - - - - -	F.A.D.A. Andrea, Inc.
Mr. H. Dreyer - - - - - - - - - - - -	Freed Eisemann Radio Corp.
Mr. Graham - - - - - - - - - - - - - -	Stromberg-Carlson Tel. Mfg. Co.
Mr. Johnson - - - - - - - - - - - - -	Hazeltine Corporation
Mr. Looser - - - - - - - - - - - - - -	Eagle Radio Company
Mr. MacDonald - - - - - - - - - - - -	Hazeltine Corporation
Mr. Manson - - - - - - - - - - - - - -	Stromberg-Carlson Tel. Mfg. Co.
Mr. Marsten - - - - - - - - - - - - -	Freed-Eisemann Radio Corp.
Mr. Miessner - - - - - - - - - - - - -	Garod Corporation
Mr. Million - - - - - - - - - - - - -	King-Hinner Radio Corp.
Mr. Russ - - - - - - - - - - - - - - -	Independent Radio Mfg. Inc.
Mr. Tyzzer - - - - - - - - - - - - - -	Amrad Corporation
Mr. Wheeler - - - - - - - - - - - - -	Hazeltine Corporation

PLAINTIFF'S EXHIBIT NO. 14-A



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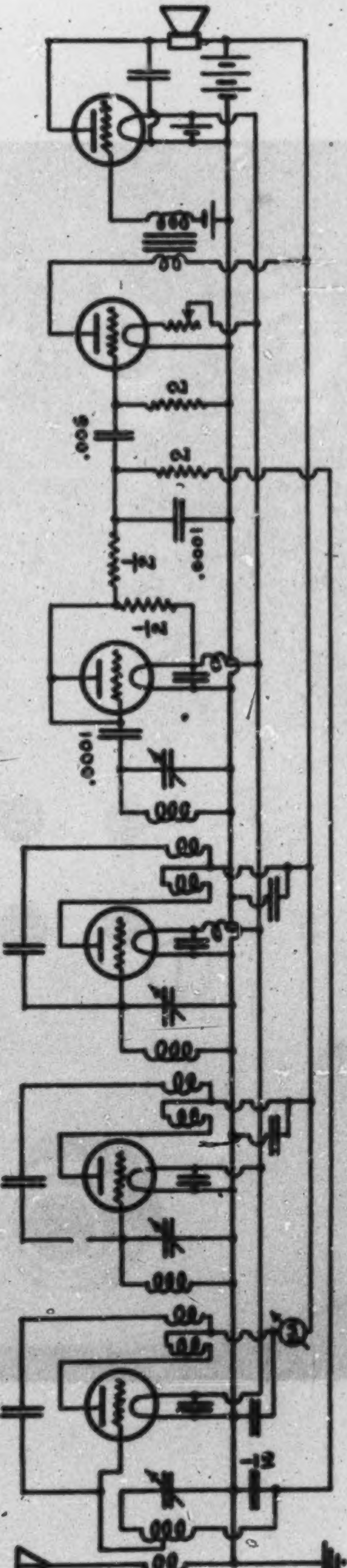
PLAINTIFF'S EXHIBIT NO. 14-B



STROMBERG-CARLSON RECEIVER

(SIMPLIFIED DIAGRAM)

(AUG., 1926)

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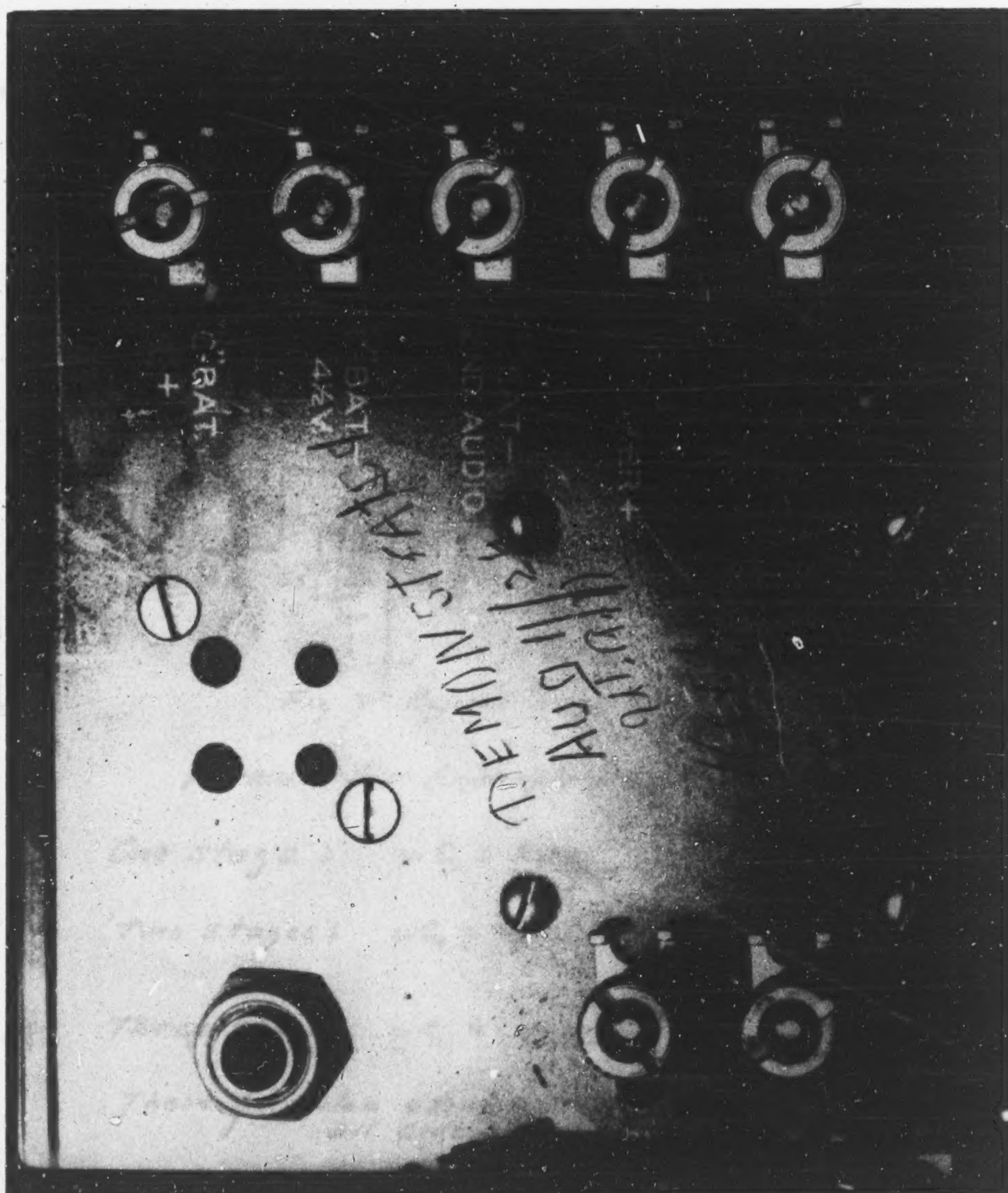
PLAINTIFF'S EXHIBIT NO. 15



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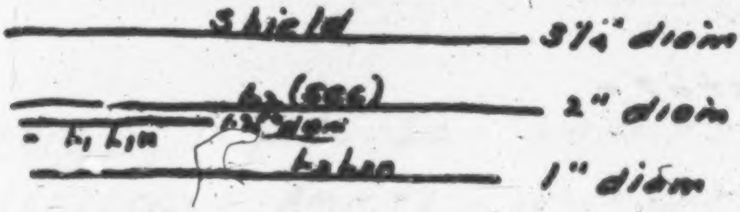
PLAINTIFF'S EXHIBIT NO. 16

Design of R.F.T. by Wheeler:



L_2 = 102 turns #24 B&S. (Standard 501 sec.)

$L_1 = L_{1n}$ = 14 turns (Standard #501 Int. stage primary)

$L_g = L_{gn}$ = 120 " " #30 B&S S.S.E.

C_g = .00035 μf.

Circuit as per fig 7 - Report of Trube's Variable ratio System June 15, 1926.

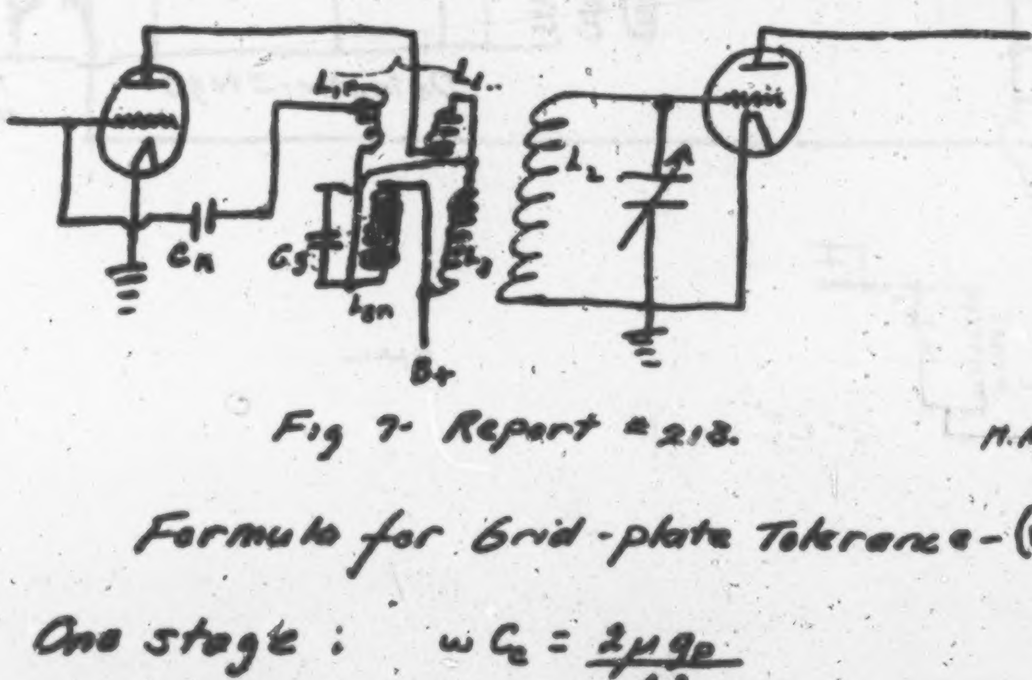


Fig 7 - Report #213.

H.A.W. / H.L.K. Aug 4th

Formula for Grid-plate Tolerance - (Wheeler)

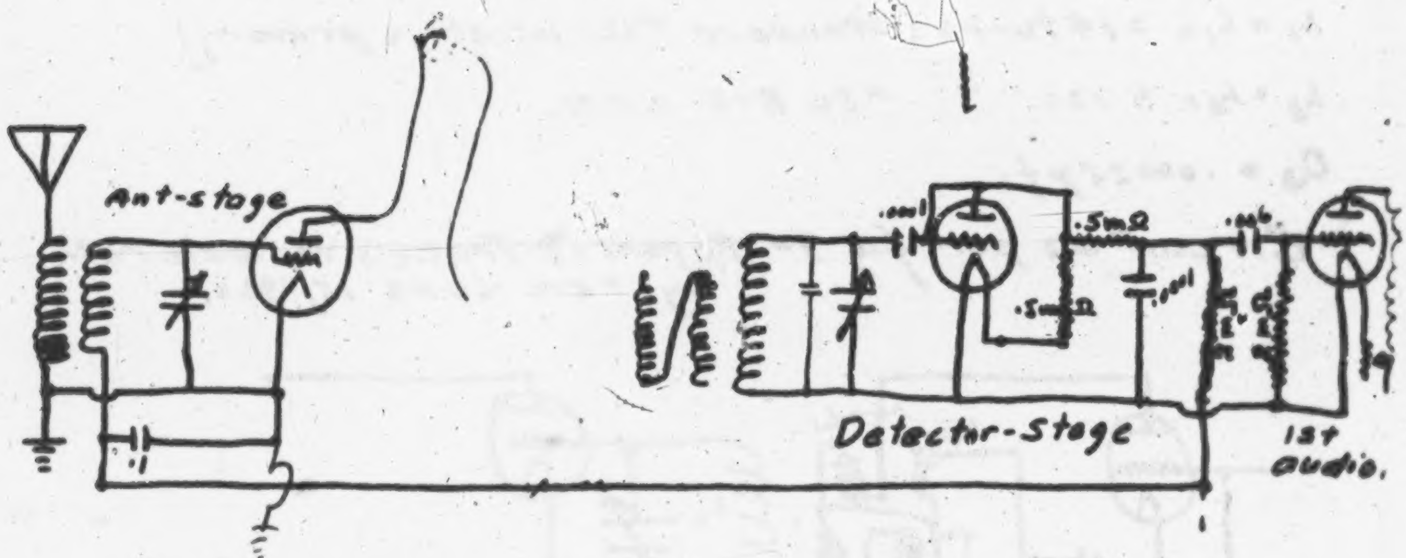
One stage: $\omega C_c = \frac{2\mu g_p}{A^2}$

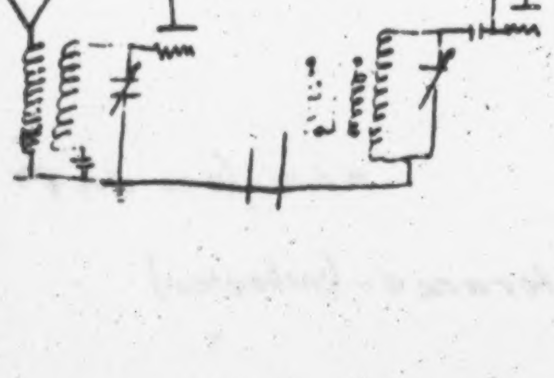
Two stages: $\omega C_c = \frac{\mu g_p}{A^2}$

Three stages: $\omega C_c = \frac{.84\,\mu g_p}{A^2}$

These formulae assume same load effective on all circuits.

- Wheelers-Audiostat -

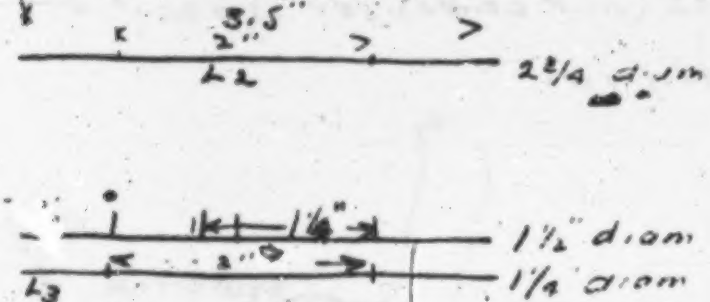




Changing tap to 20 - helps range and decreases Amp to a level of about 12.
tap at 30 - Amp becomes less (and condenser is about 30 for best tuning.) tap disqualified.

R.F. Transformer (Wheeler) (55) July [illegible] (60)

Constants:



L_2 { 65 #24 (d.c.c) tap at 55 turns; 2 3/4" diam - 2" long. }

L_3 { 160 #30 (s.c.c) 1 1/4" diam - 2" long

L_1 { 25 double turns #30 s.s.e
Threaded 20 turns per inch.
1 1/2" diam - 1 1/4" long.

Amp. Measurement

λ	θ_2	θ_1	R_2	R_1	Amp	
250	77	62.2	10	80	8.9	will not tune less than 260 Mtrs.
350	42.2	50.2	10	80	9.2	
450	27.5	18.0	10	80	9.9	
550	24.8	12.9	10	80	11.1	
250	74	61	10	80	8.8	
350	41.5	30	10	80	9.4	
450	27.0	18	10	80	9.8	
550	23.3	12.2	10	80	11.06	

Reducing Primary to 20 turns: Aug 19 '26

2[illegible]	81.5	50.2	[illegible]	80	10.2	
[illegible]	33.0	25.8	[illegible]	80	9.[illegible]5	Min - 215
[illegible]	21.0	17.5	[illegible]	80	[illegible]	Max > 560
[illegible]	16.0	10.2	[illegible]	[illegible]	16.00	

250	80.5	50.0	10	80
350	31.2			
450				
550				

AUTOMATIC VOLUME CONTROL FOR RADIO RECEIVING SETS*

By

Harold A. Wheeler

(Hazeltine Corporation)

Summary—*A receiving set is described in which the radio-frequency amplification is automatically controlled to give a nearly constant radio-frequency voltage at the detector, independent of differences in antenna signal voltage. This results in nearly uniform response at the loud-speaker from nearby and distant broadcasting stations and also reduces the effect of fading. The method employed consists in using the rectified carrier voltage to adjust the grid bias of the radio-frequency amplifier tubes. There are indicated the solutions of special problems that arise in carrying out this method.*

In the present radio receiving sets employing high amplification, it is necessary to adjust carefully a "volume control" in order to reproduce signals of different intensities with the same audible intensity from the loud speaker. There are various devices which could be employed to regulate automatically the

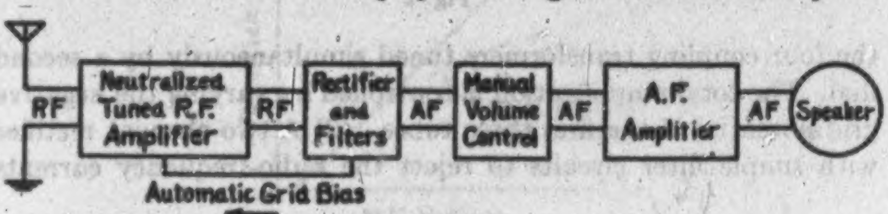


Fig. 1

amplification of the signal, some of which employ moving mechanical parts. It is the purpose of this paper to describe a simple electric circuit, without moving parts, in which the amplification is regulated automatically by the signal, and the loud speaker intensity reaches approximately the desired level for each signal, independent of the signal intensity and therefore irrespective of a reasonable amount of fading.

Any device to accomplish this object without introducing distortion of music or speech must operate by the signal carrier wave. Any variations in its intensity must be compensated by reciprocal variations in its amplification. The method to be described provides for controlling the radio-frequency amplifier, thereby maintaining the desired signal level in the detector or rectifier, audio-frequency amplifier and loud-speaker.

* Received by the Institute, October 6, 1927.

* Presented before the Institute of Radio Engineers, New York City, November 2, 1927.

Fig. 1 shows the outline of a set which has been constructed for broadcast reception, embodying this automatic volume control, comprising the following component sections. (1) A four-stage radio-frequency amplifier of the well-known Neutrodyne type, with UX 201-A tubes, the antenna circuit tuned by one dial and

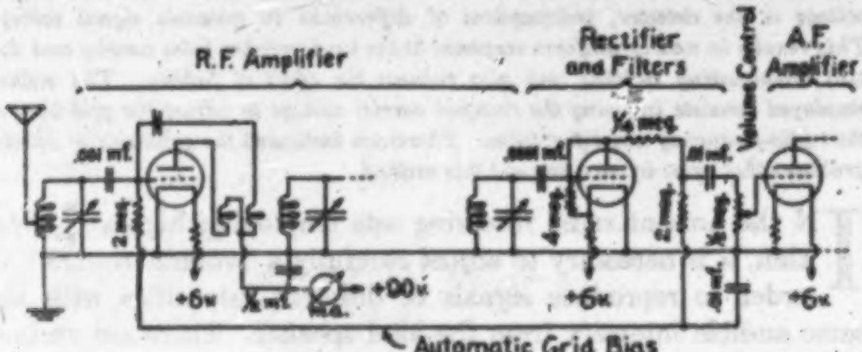


Fig. 2

the four coupling transformers tuned simultaneously by a second dial. The total amplification is controlled by varying the negative grid potential of the first three tubes. (2) A two-element rectifier with simple filter circuits to reject the radio-frequency currents

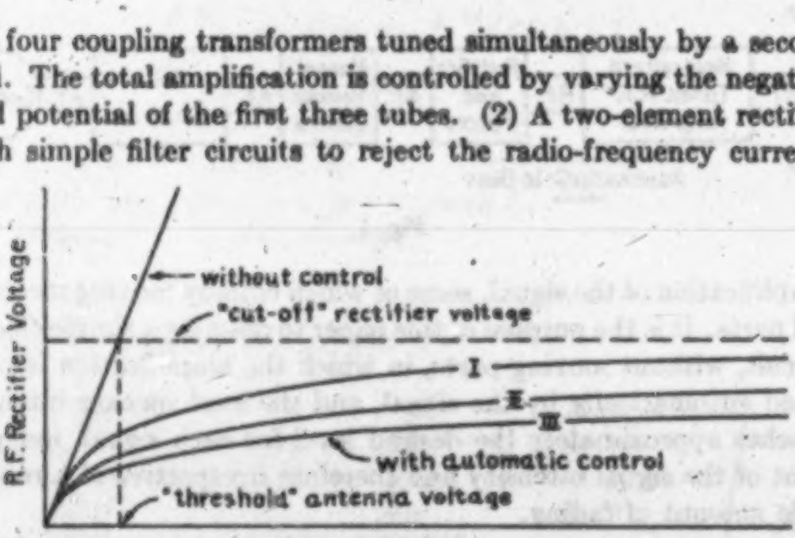


Fig. 3

and to segregate the direct and audio-frequency components of the pulsating rectified voltage. (3) A manual volume control in the form of a voltage attenuator connected to the grid of the first audio-frequency amplifier tube. (4) A four-stage audio-frequency amplifier and loud speaker. The entire set, excepting the last two audio-frequency stages, was enclosed in a grounded metal box divided into compartments, one for each tube with its preceding coupling circuit

Fig. 2 shows the essential circuit details pertaining to the control system. The direct component of the rectified voltage, free of audio-frequency variations, is applied to the grids of the first three tubes. If the radio-frequency rectifier voltage could exceed a value of about ten volts, this automatic grid bias would thereby cut off the signal through the radio-frequency amplifier, so the rectifier voltage cannot exceed this value.

Fig. 3 shows graphically the comparison between the performance of the radio-frequency amplifier with and without the automatic control. With the system described, the rectifier voltage and audio-frequency voltages are nearly independent of the an-

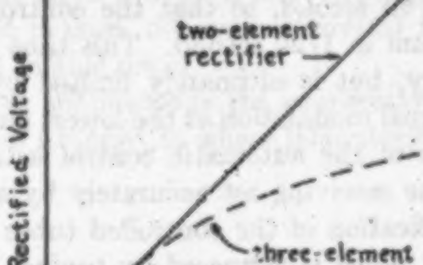


Fig. 4

tenna voltage, when the latter exceeds the threshold value. The curves I, II, and III show the performance of the system when the automatic grid bias is applied to one, two, or three tubes, respectively, of the radio-frequency amplifier.

The degree to which the signal can be cut off in one tube is limited by two factors. First, any error in neutralizing the grid-plate capacity permits signal current to pass through the tube, even when its mutual conductance is zero. Secondly, the sharp bend in the plate-current grid-voltage curve causes distortion of a strong signal on the grid, when the mutual conductance is reduced too far by the grid bias. In view of such limitations, it is undesirable to reduce the amplification ratio per stage below about 1/10 of its normal value. When controlling several tubes, these limitations become unimportant. The last radio-frequency stage is not controlled because it must supply as high as ten volts to the rectifier.

The properties of the two-element rectifier contribute largely to the simplicity of the control system. Fig. 4 shows the nearly

linear proportionality between alternating and rectified voltages in this form of rectifier, as contrasted with the irregular performance of the three-element detector. The signal modulation is rectified without distortion. Also the average rectified voltage is equal to the rectified carrier voltage, while with a "voltage-squared" detector the average rectified voltage is proportional to the average total power of carrier and sidebands. This last feature is worthy of mention in connection with the control system, since the automatic grid bias should depend only on the carrier amplitude, independent of the modulation.

With the circuit constants shown in Fig. 2, the time constant of the circuit which connects the rectifier to the grids of the control tubes is 1/40 second, so that the control system comes nearly to equilibrium in 1/20 second. This time can be reduced further if necessary, but is ultimately limited by the allowable reduction of the signal modulation at the lowest audio frequencies.

In consequence of the automatic control action, it becomes difficult to tune the receiving set accurately by ear to a desired signal. The amplification of the controlled tubes is decreased as the response to the signal is increased by tuning, and vice versa, so that the point of resonance is indicated by minimum plate current in the radio-frequency amplifier. Taking advantage of this fact, a milliammeter (*m.a.*, Fig. 2) is connected in the plate circuit of the first tube, to be used as a resonance indicator, and also to give an indication of relative signal intensities.

There is an incidental problem in supplying the plate current to all tubes of the set described from a common rectifier and filter system. In the controlled radio-frequency amplifier tubes, when operating at low plate current, the signal carrier is modulated appreciably by small fluctuations in the plate voltage. Such fluctuations are caused by the plate current pulsations in the audio-frequency amplifier. In the presence of a strong carrier wave, these two effects may cooperate to generate a low frequency oscillation. This disturbance may be avoided by reducing the internal output impedance of the rectifier-filter, by decreasing the amplification at low frequencies in the audio-frequency amplifier, or by using separate rectifier-filter systems to supply the plate currents of the radio- and audio-frequency amplifiers, respectively.

The performance of the automatic volume control as described can be summarized briefly as follows. A maximum variation of signal voltage in the ratio of 1:1900, corresponding to differences in distance, fading, or tuning, results in a maximum variation of

the rectified carrier voltage in the ratio of only about 1:3. This small variation, together with possible differences in the degree of modulation of different stations, can readily be compensated if necessary by adjusting the manual volume control for the audio-frequency amplifier, which also determines the "volume level" for the automatic volume control.

The name "Audiostat" has been selected for this device, by reason of its tendency to maintain the audible intensity at a constant value.

Attention might be called to British Patent 250,664 (Western Electric Co., July 14, 1925), in which a somewhat similar system is presented. This latter system is applied to a super-heterodyne receiving set, and is more involved in several respects than the system described in this paper.

It is desired to acknowledge the cooperation of the Howard Radio Company of Chicago, in whose laboratory the set described was assembled.

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PLAINTIFF'S EXHIBIT NO. 18

PHILCO BALANCED-UNIT RADIO SERVICE MANUAL FOR MODEL 95

Philco Model 95

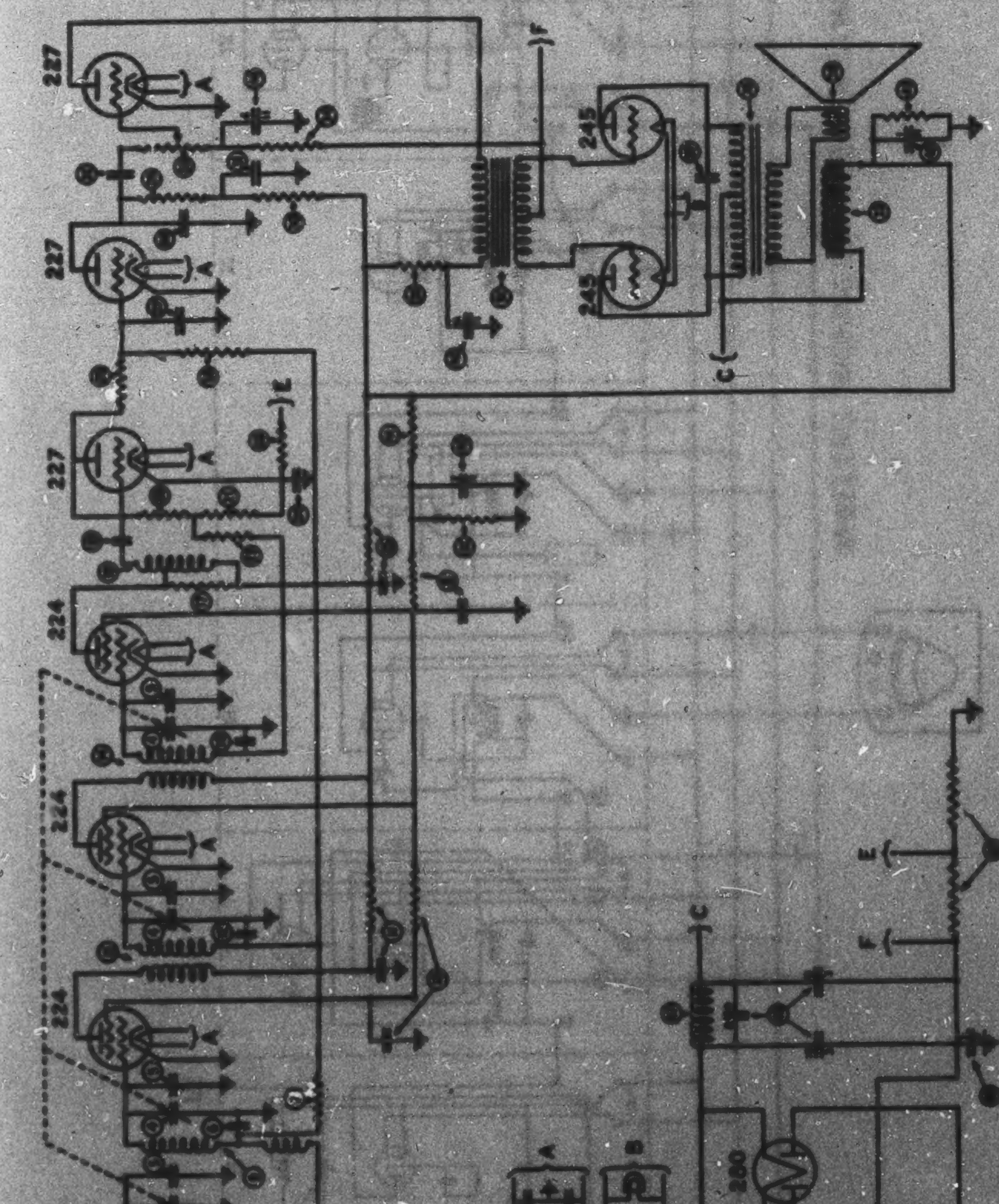

Fig. 1

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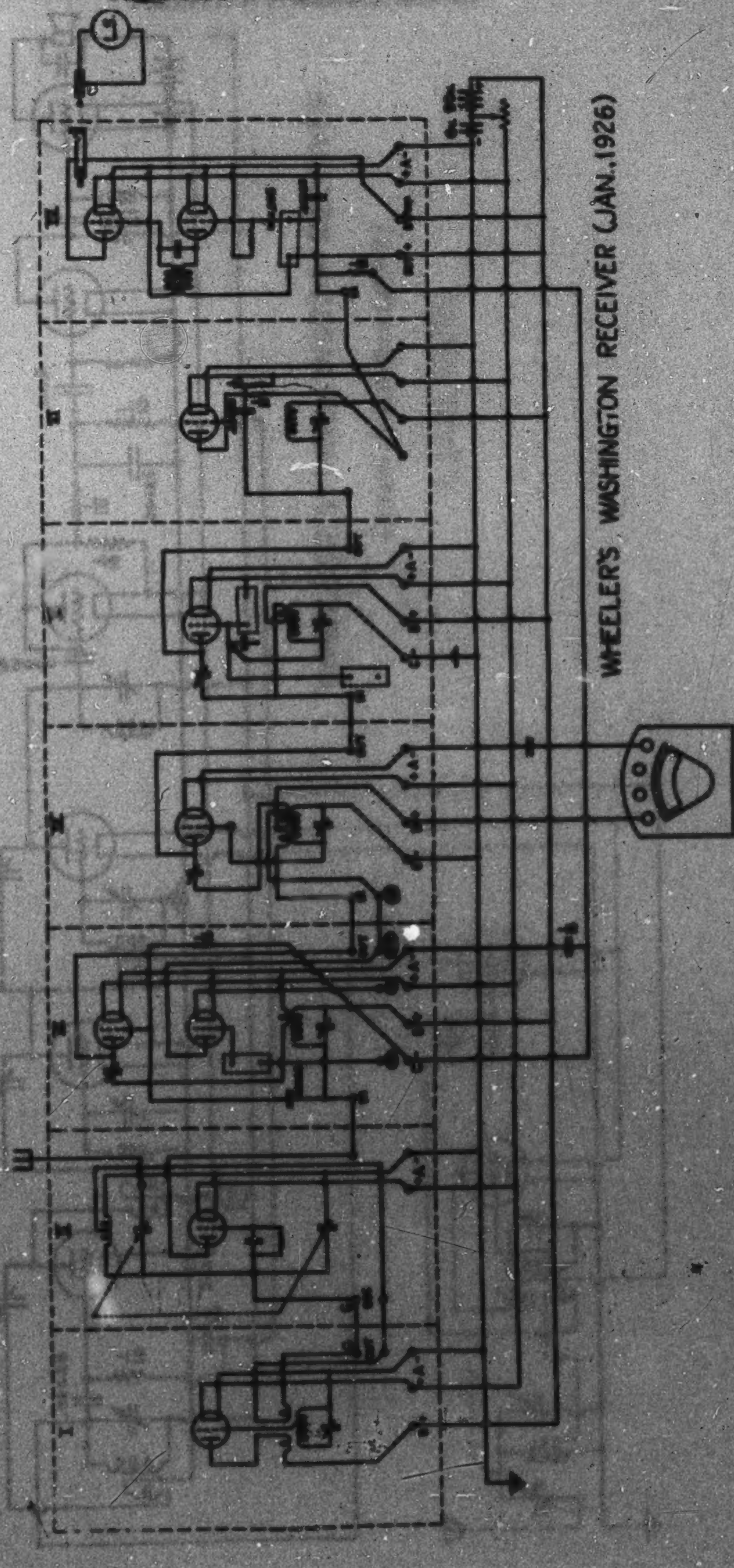

WHEELER'S WASHINGTON RECEIVER (JAN.,1926)

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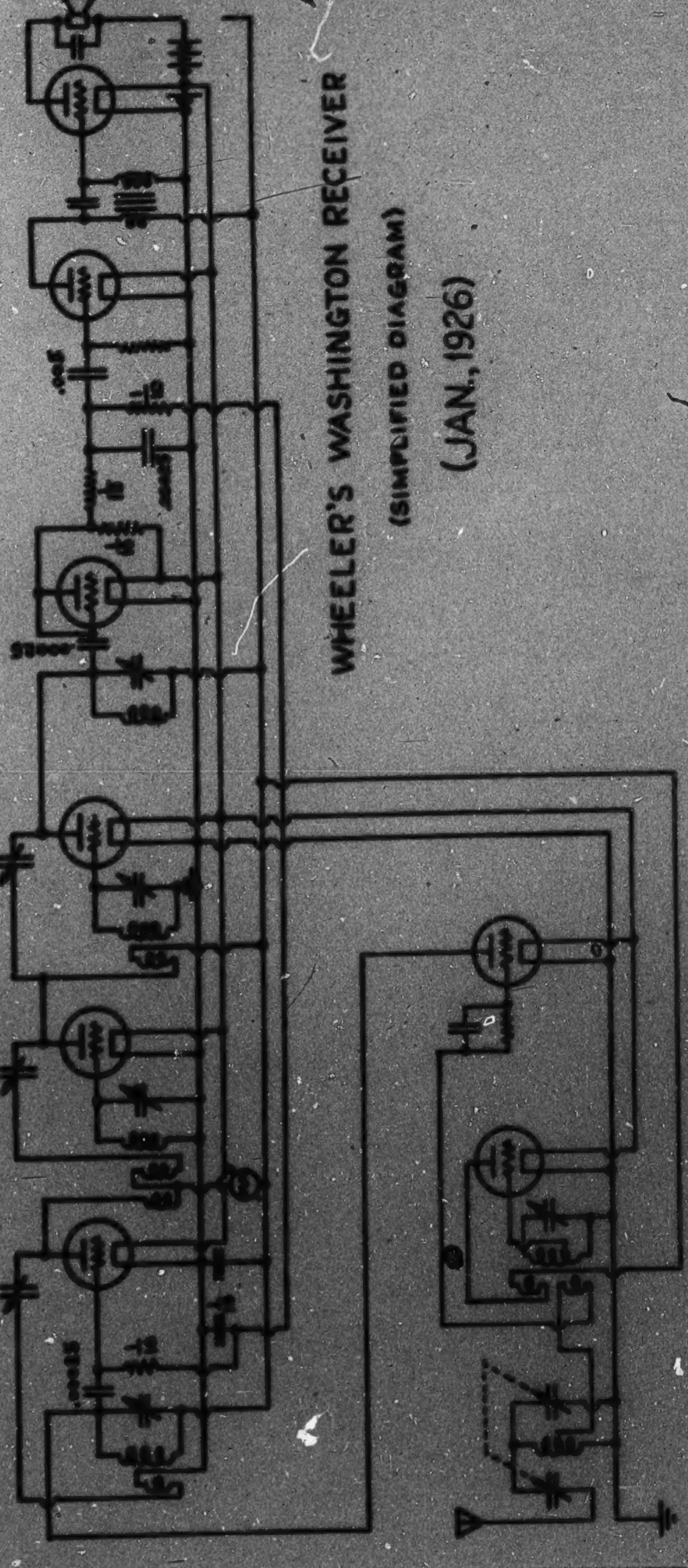

WHEELER'S WASHINGTON RECEIVER

(SIMPLIFIED DIAGRAM)

(JAN., 1926)

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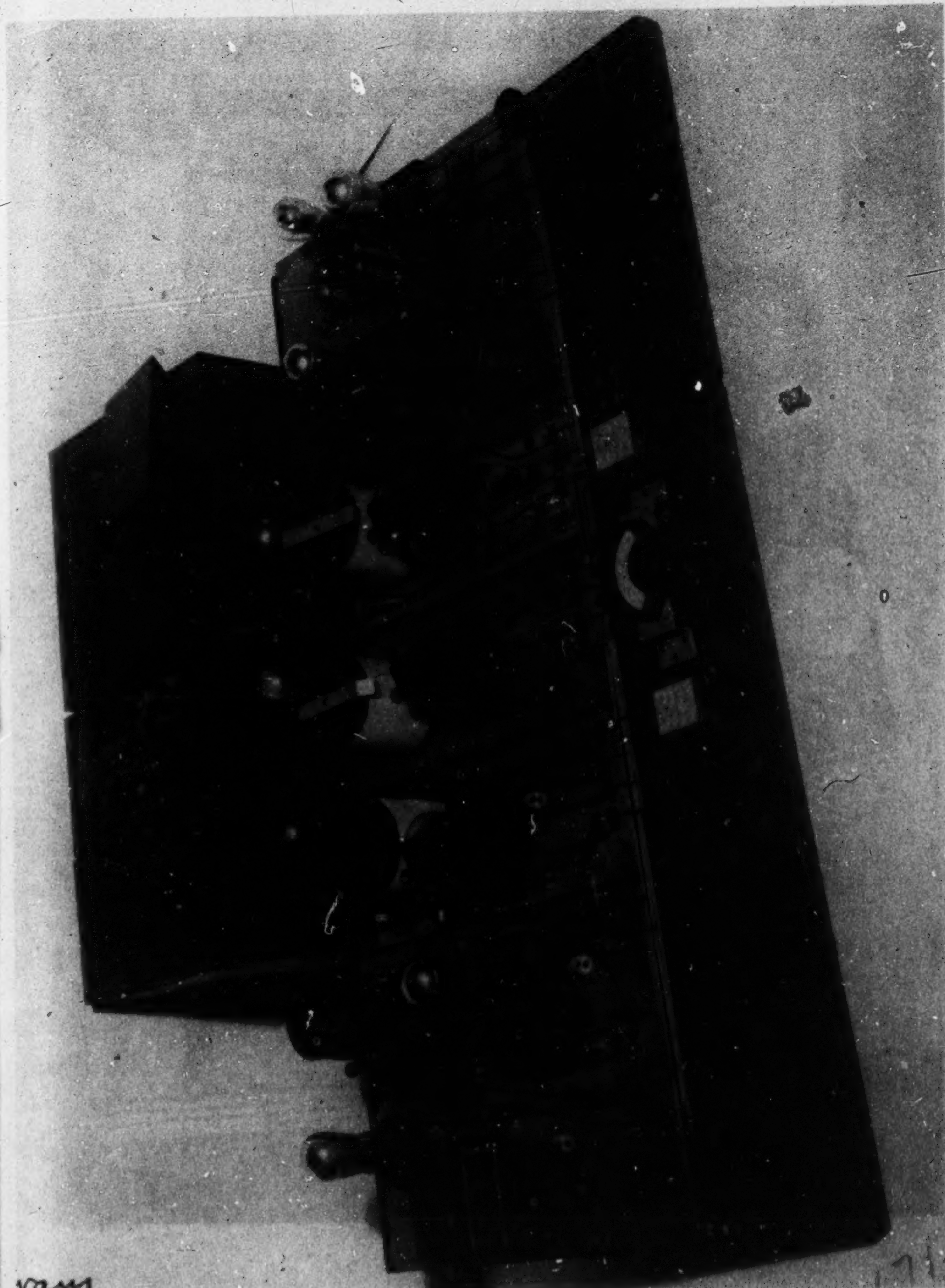

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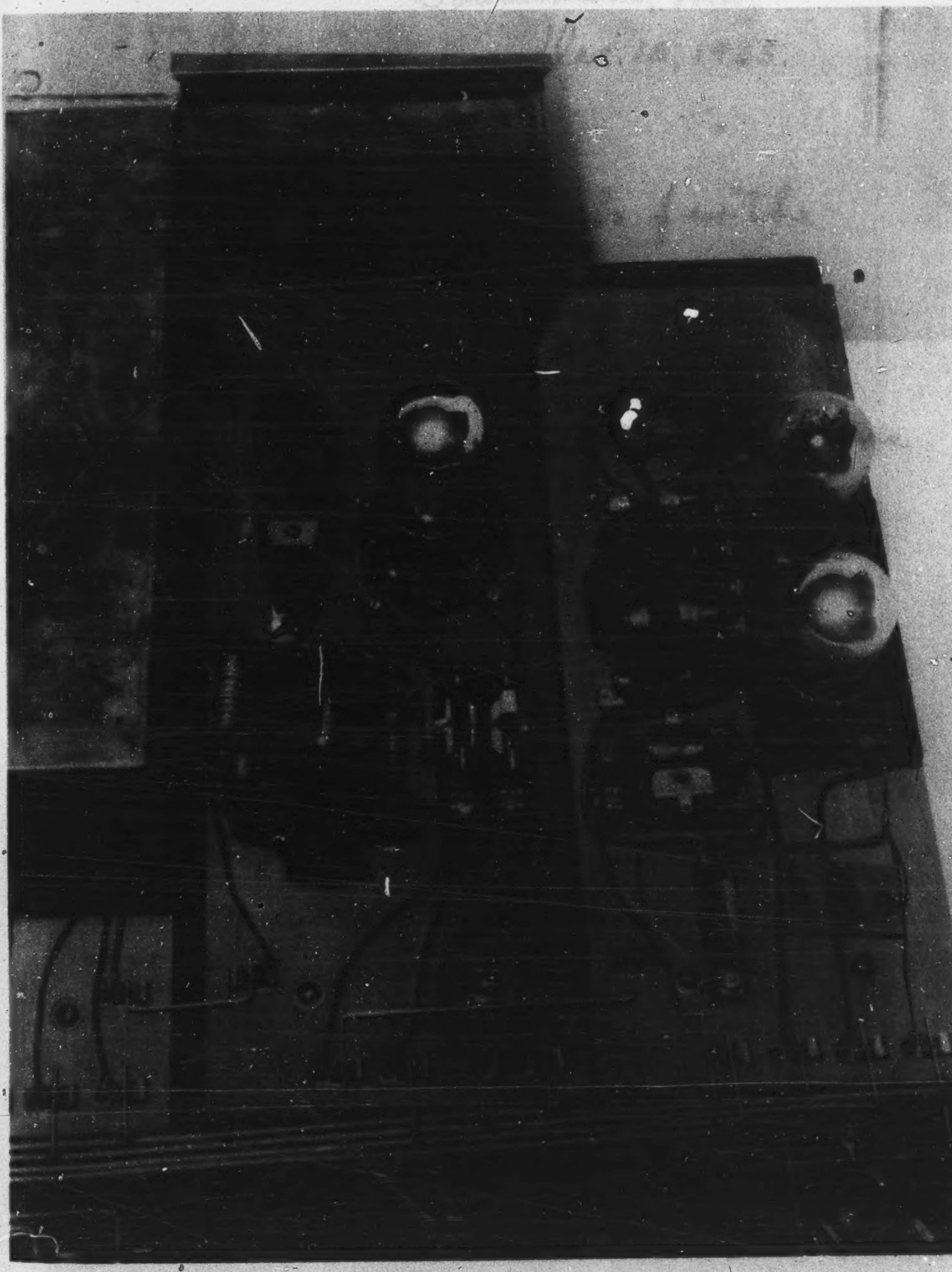

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PLAINTIFF'S EXHIBIT NO. 24-A

Baltimore, Md.
Dec. 15, 1925.

Dear Dreyer,

Here is a check for the tubes, and thank you very much for the accommodation to me.

Your letter was very interesting, especially with reference to the possibilities of ~~the~~ your brother's joining us.

I hope to build the new volume control into a receiver at my home during the holidays, in which case I may ask you and some of the others to come down and look it over early in January. I think I can work it now with only one added tube!

Sincerely yours,

Harold A. Wheeler

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PLAINTIFF'S EXHIBIT NO. 24-B

HAZELTINE CORPORATION
15 EXCHANGE PLACE
JERSEY CITY, N. J.

December 24th, 1925.

Mr. Harold A. Wheeler,
Baltimore, Md.

Dear Wheeler:-

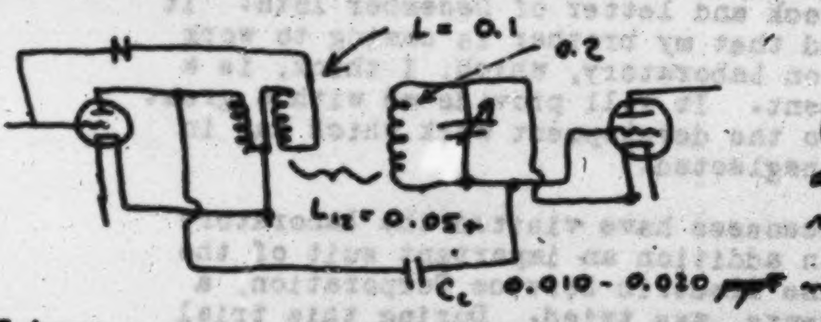
Thank you for your check and letter of December 15th. It is quite definitely decided that my brother is coming to work at the Hazeltine Corporation Laboratory, which, I think, is a very satisfactory arrangement. It will provide me with a great deal more time to devote to the development work which has in the last month been sadly neglected.

In this time seven licensees have visited the Laboratory with specific problems. In addition an important suit of the Hazeltine Corporation vs the Electric Service Corporation, a gross infringer of our patents, was tried. During this trial the Electric Service Corporation put up a very stiff defense citing Rice, Goldsmith and Weinberger and about everything else they could dig up. They made rather a point of the fact that in their receiver almost an exact duplicate of the early Freed-Eisemann and so forth the coupling coefficient between the primary and secondary (we contend that the thing should be considered coefficient between primary and tap portion of secondary) was not substantially equalled to unity. Measurements made here in the laboratory by me and which I had the opportunity to swear to on the witness stand, indicated that the coupling tap portion to secondary was 72 per cent whereas the coupling of the whole secondary was but 48 per cent. Notwithstanding this I believe the suit will be decided in our favor.

With regard to your coupling device, the work done on it has been very small and unsatisfactory in that we have not as yet made a set sufficiently stable. The limitation seems to be that very close coupling is necessary even though the plate neutralization is employed. Oscillations apparently occur at various resonant periods; sometimes of the choke alone, and sometimes of the choke plus coupling condenser. My feeling is that the real limitation is not coupling coefficient but leakage inductance and, therefore, since the total amount of inductance in the primary side is less than in the secondary it is more desirable to accomplish neutralization by grid to grid methods/ to plate

Mr. Harold A. Wheeler   Page Two.

During the course of the trial just mentioned, the question of capacity coupling between primary and secondary was brought up. The defense made rather a point of this. I computed it as well as I was able for the conventional neutrodyne, and was surprised to find that it was of the order of several per cent of the inductive coupling and that it apparently increased very rapidly with primary inductance. For this reason, I am proposing the following arrangement for obtaining variable coupling. It is in many respects similar to yours and would probably be covered in your earlier specifications.



Note: The capacitive coupling varies with the frequency and is negative with respect to the inductive coupling. There must be considerable leakage inductance in primary circuit. If not sufficient this may be increased with a series inductance which is also provided with a neutralizing winding.

I have not as yet tried this but am having coils built now. It seems possible to use "grid to grid" neutralisations with this without introducing too high a minimum capacity or dielectric loss.

I was interested in your comment about your new volume control. I hope that you are successful with accomplishing your desire with but one additional tube and would be very glad indeed to visit you during January if you are successful. Perhaps at this time we could also go over the best procedure with regard to the variable coupling devices.

Sincerely yours,

John F. Dreyer Jr.

John F. Dreyer, Jr.

PLAINTIFF'S EXHIBIT NO. 25

HAZELTINE CORPORATION
LABORATORY
521 RIVER STREET
HOBOKEN, N. J.

April 14, 1926.

Mr. R. T. Pierson,
120 Broadway,
New York City.

Dear Mr. Pierson:

I am writing you herewith describing the developments of Mr. Wheeler in Washington.

His principal invention is what he terms an "Audiostat". This device or rather circuit has the property of automatically controlling the volume of the signal regardless of its actual intensity. If applied to a single dial Neutrodyne, the operation would be as follows: The desired volume would be adjusted once during the evening and then by merely turning the dial all stations in the wave length range would come in at the same intensity. The weaker stations, of course, would have a greater proportion of static than the locals.

The device operates by automatically regulating the intensity of the carrier wave on the grid of the detector tube. By doing this, fading of moderately distant stations is eliminated. The device demonstrated to me was applied to a Super Heterodyne. However, there is no reason why it could not be applied to a multi tube shielded Neutrodyne receiver.

I was very much impressed by the operation of this device and believe that it would be advisable to submit it to the licensees. This could best be done, I think, by inviting Mr. Wheeler to one of the engineering meetings I planned and have him tell them at that time.

Another development of Mr. Wheeler's which I think would be of interest to Neutrodyne manufacturers is a clever mechanical device for converting a two dial receiver into a single control receiver. This consists of connecting all condensers including the antenna tuning condenser on one shaft. This shaft is turned by a knob which is free not only to rotate, but also to move in an axial direction. The rotation of the knob causes all of the condensers to be rotated whereas the axial motion of this knob "in and out from the panel" adjusts a vernier condenser in parallel with the antenna tuning condenser. This is to compensate for the differences between the antenna circuit and the other circuits.

Very truly yours,

John F. Dreyer Jr.

~~Development Engineer~~

JFD:GT

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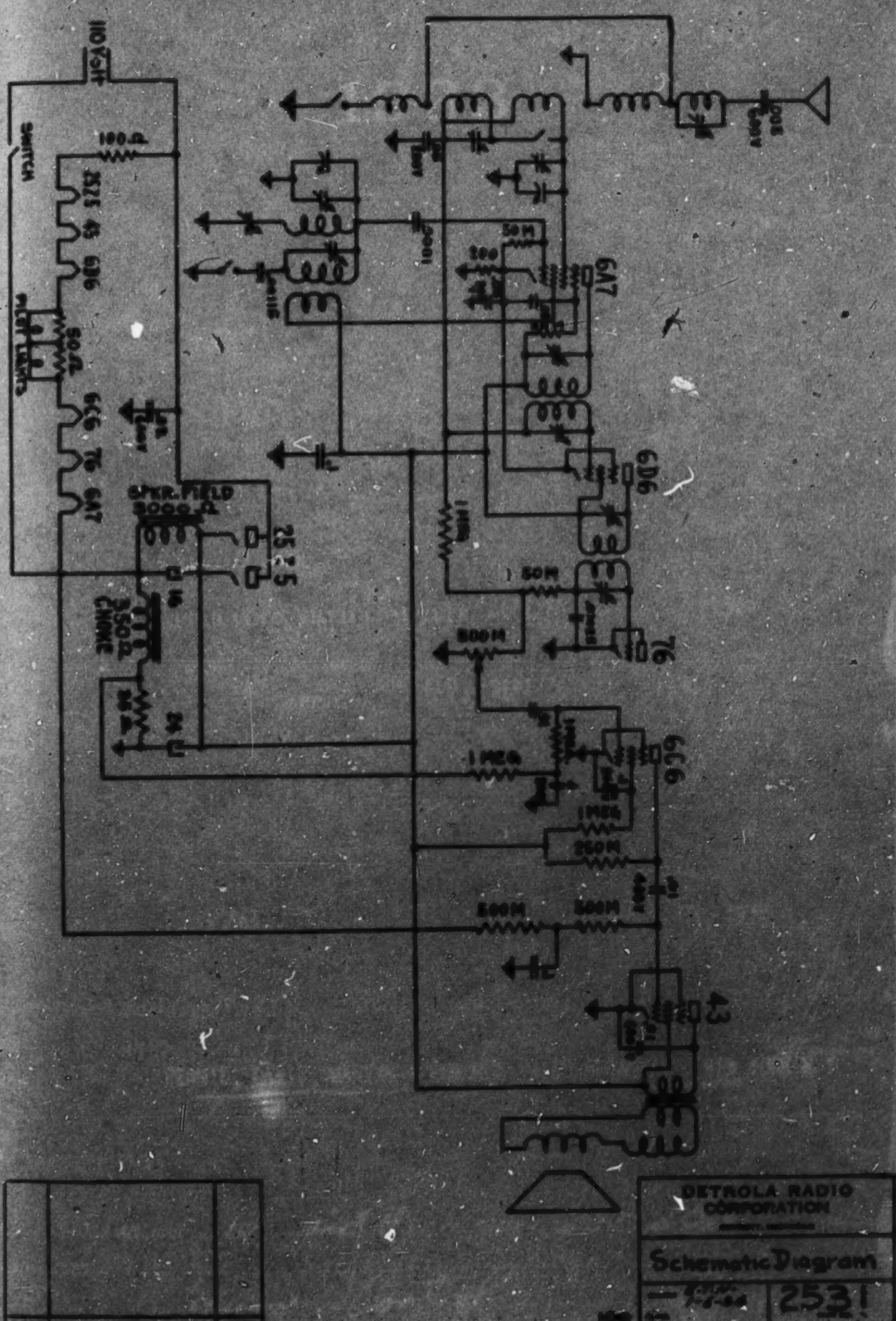

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DEFENDANT'S EXHIBIT A

REISSUE NO.

1933

DATED

EX'R'S Book

DIV

A. FELLER

FLAME CONTROL

APPLICATION FILED COMPLETE. SEPT 26 1934

ORDERED SEPT 26 1934

2

1,879,863 SEPT. 27, 1932

PENNIE, DAVIS, MARVIN & EDMONDS 165 BROADWAY NEW YORK N Y

No. Claims Allowed 13 Print Cl 1 Class 250-20

Title as Allowed

Flame Control

PENNIE, DAVIS, MARVIN AND EDMONDS
COUNSELLORS AT LAW
165 BROADWAY
NEW YORK

... DAVIS
... D. MARVIN
... S. EDMONDS
... E. BARROWS
... BROWN MORTON
MERTON W. SAGE
WILLIS H. TAYLOR, JR.
ERNEST H. MERCHANT
GEORGE E. MIDDLETON
MORRIS D. JACKSON
R. MORTON ADAMS
RAYMOND F. ADAMS
LESLIE B. YOUNG
DANIEL V. MAHONEY

RAYMOND B. CANFIELD
BALDWIN GUILD
AMBROSE A. ARNOLD
S. HOWELL BROWN, JR.
LOUIS D. FORWARD
GEORGE E. FAITHFULL
WALTER H. FREE
DONALD M. CARTHY
RAYMOND T. M. ...
JOHN BOYLE
D. GORDON ANGUS
JOHN T. FARLEY
CURT VON BORTSCHER, JR.

SEP 26 34

Sir:

specification,

filin

of which

93424T

B 691

SEP 26 34
U.S. PATENT OFFICE

P E T I T I O N

TO THE COMMISSIONER OF PATENTS:

Your petitioner, HAROLD A. WHEELER, a citizen of the United States, residing at Great Neck, Long Island, in the County of Nassau, State of New York, whose post office address is 18 Melbourne Road, Great Neck, Long Island, prays that he may be allowed to surrender the Letters Patent for an Improvement in "Volume Control" 1,879,863, granted September 27, 1932, whereof HAZELTINE CORPORATION, a corporation of Delaware on whose behalf and with whose assent this application is made, is now sole owner, by assignment, and that Letters Patent may be reissued to the said HAZELTINE CORPORATION for the same invention upon the annexed amended specification. With this petition is filed an order for a certified copy of the abstract of title to be placed in the file, as required in such cases; and

Your petitioner hereby [illegible] Davis, [illegible] Edmonds, [illegible] [illegible] Middleton, [illegible] F. Adams, [illegible] Davis (constituting [illegible] Davis, [illegible] & Edmonds, 120 Broadway, New York City, [illegible] 10659) and each of them, his attorneys, with full power of substitution and revocation, to prosecute this reissue application,

[redacted]

D3871-Re [illegible] 934250

This invention relates to amplifiers, and more particularly to amplifiers utilized in [illegible] carrier-current signalling systems [illegible] amplification is automatically [illegible] predetermined level.

This application is [illegible]

[illegible]

B 695

It has also been a common experience in the use of former radio receivers that the reproduced signal was not uniform due to the phenomenon of "fading", whereby the received signal occasionally, or periodically, became much weaker, or faded almost to the point of inaudibility. Since the present invention provides an amplifier which automatically compensates for inequalities in the received carrier-current signal strength, when "fading" takes place the degree of amplification is correspondingly increased and the reproduced signal maintained at its former volume, so that a listener is unaware that variation of the received carrier-current signal is occurring. This automatic compensation for signal fading is especially advantageous in [illegible] telephony and [illegible].

[illegible] is the saving in plate current which is automatically [illegible] invention [illegible] current [illegible]

[illegible] Radio [illegible]

A second stage of radio-frequency amplification including the vacuum tube 15 neutralized by cooperation of coil 26 and condenser 4, like the first stage, comprises the secondary winding 16 of the last-mentioned radio-frequency transformer tuned by a variable condenser 17 connected between the filament system of the vacuum tube 15 and the grid 18 thereof. The output circuit of this vacuum tube also includes the high-voltage battery "B" and a primary winding [illegible] of a second radio-frequency transformer, while the secondary winding 21 of this transformer tuned by a variable condenser 22 is included in the input circuit of a third [illegible] which includes vacuum-tube 23. The inherent capacity effective between the electrodes 24 and 25 is neutralized by a network including the neutralizing condenser [illegible] and the neutralizing winding [illegible] outputs. The output circuit [illegible] the primary winding [illegible] of a [illegible] transformer and the high-voltage [illegible] winding 31 of this last-[illegible] a variable [illegible] of a rectifier 33 which [illegible] condenser [illegible] commonly known [illegible] valve, [illegible]

It may here be noted that throughout the present specification and claims the terms "rectifier" and "detector" are, in general, used interchangeably, the terms "rectifying" and "converting" being employed in the general sense to include the process of changing alternating current into a form of direct current or modulated unidirectional current. Likewise, the terms "carrier-current" and "modulation current" may be substituted, respectively, for "radio-frequency current" and "audio-frequency current", since the description herein of radio-frequency amplifiers and audio-frequency amplifiers is merely by way of example of a typical embodiment of the present invention.

In the absence of the present invention including the control circuit 36, to be described, the three-stage tuned radio-frequency amplifier, including the vacuum tubes 9, 15 and 23, functions in a manner well-known in the art to amplify the incoming signal intercepted on the antenna 5. The output circuit of the rectifier 33 includes what may be termed a "rejector" circuit for stopping radio-frequency currents which have passed through the rectifier, and consists of a network including a resistance 34 and a by-pass condenser 37 connected between the anode 35 and the filament 36 of the rectifier. The output circuit of the rectifier is coupled to the input circuit of an audio-frequency amplifying vacuum tube 39 through an audio-frequency-pass filter including a fixed condenser 40 and a resistance 41 connected between the filament 42 and the grid 43 of this vacuum tube. Through ~~this filter~~ the audio-frequency component ~~is transferred~~

to the input circuit of the audio or modulation-frequency amplifier, while preventing the unidirectional component from being impressed upon the input circuit thereof. The output circuit of this amplifier is connected between the filament 42 and plate 44 through the high-voltage battery "B" and the primary winding 45 of an audio-frequency transformer, the secondary winding 46 of which is connected in the input circuit of a second audio-frequency tube 47, while a resistance 48 connected across the winding 46 serves to give the audio amplifier substantially uniform amplification over the desired frequency range. Instead of employing resistance 48, a closed copper band of suitable size may be placed around the transformer winding so as to be electromagnetically coupled thereto. A loud speaker or other reproducing device 52, or if required, a coupling device for a telephone system, is connected in the output circuit of the last audio-frequency amplifying tube 47. It is presumed that adequate precautions against undesired electromagnetic coupling between the various radio-frequency coupling transformers are included in all of the arrangements herein disclosed.

Ins B

Insert (B) Pen B

In accordance with the main feature of the present invention, ~~means are provided to control automatically the~~ degree of amplification effected in the radio-frequency amplifying stages. (B) ~~These means include~~ a resistance 51, connected between the filament [illegible] and the anode [illegible] of the rectifier, through which the pulsating rectified or converted current flows, thereby developing a negative voltage at terminal [illegible]. This negative voltage is applied over conductor [illegible] through the resistance [illegible] and the secondary

winding 7 of the first radio-frequency transformer to grid 11 of the first radio-frequency stage. Resistance 53, together with blocking condenser 54, is effective to filter out and reject any audio-frequency ~~currents~~ voltages which otherwise might be ~~present in the~~ applied from conductor 36 to the grid 11.

To complete the description of the system illustrated in Fig. 1 certain design data or constants are given herewith. It should be understood, however, that these, as well as all other constants appearing in the present specification, are mentioned merely by way of example in describing certain specific embodiments which in practice have proved eminently satisfactory, and are not intended to suggest any specific limitations as to the scope of this invention. Accordingly, fixed condenser 2 may be of [illegible] microfarads; 37 of 0.0001 microfarads; 54 of 0.01 microfarads; 40 of 0.005 microfarads; resistance [illegible] 1 megohm; 34 of 1 megohm; and 33 and [illegible] of 2 megohms each. The tubes may be [illegible] of the well-known 201A type.

In the operation of the receiver shown in Fig. 1 a signal intercepted on the antenna 5 is successively amplified through the neutralized tuned radio-frequency stages indicated by the vacuum tubes 9, 15 and 23, connected in cascade. This amplified signal voltage is then rectified by the rectifier 33, and the rectified pulsating current is successively amplified by the audio amplifying stages including vacuum tubes 39 and 47, after which it may be reproduced as sound by the loud speaker 50.

The high resistance 51 connected between the filament 38 and the anode 35 of the rectifier, through which a small space current flows in the absence of signal output from the radio-frequency amplifier, maintains the anode normally negative relative to at least part of the filament of the rectifier. Since all the filaments are connected in parallel, the rectifier filament is maintained at substantially the same potential as the filament 27 of the first radio-frequency amplifier tube 9. Therefore the resistance 51 is connected effectively between the rectifier anode 35 and the amplifier filament 27, and thereby maintains the rectifier anode normally negative relative to at least part of the amplifier filament.

When the amplified or rectified signal current (or space current) flows through the space current circuit including resistance 51 increases above [illegible] a predetermined value, there [illegible] terminal 32 sufficient ~~thereacting~~ negative biasing voltage, which in turn is impressed, through the direct-current connection including [illegible] 11 of the vacuum tube 9, to reduce the amplification of this tube. Conversely, it

71

will be apparent that as the magnitude of the rectified current flowing through resistance 51 decreases with decreasing signal strength, the voltage at terminal 52 becomes less negative, and the negative biasing voltage impressed upon the grid 11 also diminishes so that the vacuum tube 9 effects an increased degree of amplification. In this manner, the radio-frequency voltage applied to the input of the rectifier is maintained at a nearly constant predetermined value, and the volume of the reproduced signal is substantially uniform under all conditions. The limit at which ~~degree~~ the volume is maintained uniform is [illegible] ~~of volume or the arbitrary volume level of the reproduced signal desired by the listener is~~ then determined by adjustment of rheostat 4[illegible] which controls the heating current in the filament 4[illegible] of the first audio-frequency amplifying tube 3[illegible].

In the above operation it is noted that the two-electrode rectifier [illegible] functions as the grid detector and also effects rectification upon the radio-frequency carrier current to control amplification in the first radio-frequency stage of the receiver. The audio-frequency component of the detector output is transferred to the input circuit of the audio-frequency amplifier for further amplification.

The neutralization of the grid-plate capacity of the radio-frequency amplifying tube 1[illegible], in connection with the present invention, particularly valuable in that it allows an increase in the effective [illegible] of the amplification [illegible], because such neutralization prevents radio-frequency energy from passing through the grid-plate capacity of the tubes. Thus the relay action of the tubes is almost entirely subject to the control by grid bias voltages provided in accordance with this invention.

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The time required for operation of the control system would ordinarily be determined by the lowest audio-frequency modulation which must be reproduced. Fading, for example, might be considered a form of modulation; the frequency of the rise and fall of signals due to fading being the frequency of modulation. If this frequency of modulation be increased sufficiently, the effect will be audio-frequency modulation. It will thus be seen that if the automatic control attained by the present invention be allowed to respond too quickly, it will tend to [illegible] the desired modulation of the signals at the lower audio frequencies. Hence, a time constant of operation is chosen which will be greater than the period of the audio fre-quencies which the system is intended to amplify. The time constant of the control circuit is equal to the product of the series resistance and the shunt capacitance of the grid bias circuit, [illegible] between [illegible] and the anode terminal [illegible] in the direct-current connection back to the grid [illegible], and [illegible] connected between the amplifier filament [illegible] [illegible] greater than required from the point of view of satisfactory audio-frequency quality in the reproduction of music, there

appears to be no need for more rapid control under the conditions usually encountered. The use in this connection of condensers of large capacitance, such as one-tenth microfarad, likewise introduces another convenience in that the condensers may also serve to by-pass radio frequencies in order to prevent undesired coupling between the detector circuit and the first radio-frequency amplifying tube because of some impedances common to those two portions of the apparatus.

The milliammeter 10 is connected in the anode circuit of the amplifying vacuum tube 9. Upon receipt of an amplified signal at the detector, the effect of the control circuit is to decrease the plate current through milliammeter 10, thereby reducing the amplification in the tube 9. When the receiver is tuned to the signal frequency, a minimum amplification is required, so that when the condition of resonance is attained, the plate current of tube 9 is at a minimum value, and the milliammeter 10 so indicates. Thus the milliammeter visually indicates the condition of resonance.

[illegible] other embodiment of the present invention [illegible] Fig. 2. It will be appreciated that [illegible] similar to that illustrated in Fig. 1, but in which [illegible] for automatically limiting the degree of amplification is included, the amplified radio-frequency voltage is proportional to the radio-frequency antenna voltage, as indicated by curve [illegible]. When, however, the present invention is embodied in such an amplifier, the relation between the radio-frequency antenna voltage and the amplified radio-frequency voltage is indicated by curve

103 from which it will be seen that when at least a [illegible] predetermined radio-frequency antenna voltage is present, (herein referred to as the "threshold antenna voltage") the amplified radio-frequency voltage [illegible] — is always less than [illegible] output [illegible] voltage value (herein referred to as the "output [illegible]").

[illegible]

vacuum tube 71 to a second audio-frequency amplifying tube 77. This last vacuum tube in turn is coupled by a second audio-frequency transformer 78 to a third audio-frequency amplifying tube 79 in the output circuit of which there is included a loud speaker 80.

In this arrangement automatic amplification control is effected in a manner slightly different from that shown in the diagram of Fig. 1, since in this instance the radio-frequency voltage of the signals intercepted by the antenna 56 is successively amplified by three neutralized tuned radio-frequency amplifying stages including the vacuum tubes [illegible] and 62, of which two (instead of one) are controlled in accordance with the present invention. The amplified radio-frequency current is rectified by the rectifying valve [illegible], [illegible]

the negative voltage at terminal 81 tends to increase with the increased signal, the resulting increase of biasing voltage impressed upon the grids of the tubes 58 and 60 limits the degree of amplification effected in the radio-frequency stages including those tubes.

In this arrangement the constants for the various resistances and condensers may, for example, be the same as those for the corresponding elements in Fig. 1. In addition the grid resistances 63 and 65 may have a value of 2 megohms each; and the grid condensers connected at the junctions of these resistances and the grid electrodes 64 and 66 may each be of 0.001 microfarad capacity.

In Figs. 1 and 3 the variable tuning condensers are grounded in order to eliminate undesirable capacity effects as well as to make it practicable to connect the condensers on a single shaft for unit control, if desired.

There are advantages attending the use, in connection with the present invention, of the two-electrode rectifier circuit typified by Figs. 1 and 3, as will be apparent from the foregoing discussion. It is impossible to overload this type of rectifier, and the rectified output voltage is directly proportional to the applied alternating signal voltage when this voltage is large, say over two volts. The control system in the circuits of the figures referred to requires a large operating voltage, say ten volts, so that the latter condition of large signal voltage is realized. No such simple relationship is possible in a three-electrode detector, whose rectified output never exceeds a limiting upper value, and is never proportional to the applied voltage, except over a very small range of

voltages. This distinction will be seen from Fig. 4 where the abscissae "A. C." represent the alternating signal voltages, whereas the ordinates "D. C." represent the rectified output voltages. It is well known that the linear curve is much more desirable when minimum distortion of a modulated signal is desired, and it will be observed from Fig. 4 that the [illegible] type of curve is obtained from the two-electrode rectifier.

~~A three-electrode detector would be useful for relatively small applied voltages,~~ and the rectified output voltage would be approximately proportional to the square of the applied voltage, i.e., [illegible] associated with the applied voltage. [illegible] rectified voltage would [illegible] wave distortion. [illegible] automatic amplification control system the total power [illegible] sub- stantially constant [illegible] wave [illegible] it is desirable [illegible] [illegible]

[illegible]

[illegible] two-electrode [illegible] valve [illegible] rectifier [illegible] requires [illegible]

Rr. B

Insert B

In the foregoing description, tuned radio-frequency receivers of the neutralized type have been referred to. It should be pointed out, however, that the [illegible] present invention ~~may be employed~~ with equal effectiveness ~~to any~~ radio receivers in wired radio and similar [illegible] systems, and that it has been found especially [illegible] to receivers of the super-heterodyne type.

It is well-known that the usual "B" battery may be replaced by a source of rectified and filtered alternating current, and, in the event that [illegible] heated cathodes are used instead of the usual [illegible] filament cathodes, the usual "A" battery may be replaced by a source of alternating current.

For these reasons [illegible] [illegible] stood as [illegible] [illegible] [illegible]

B 714

What is claimed is: [illegible]

1. In a signaling system a vacuum tube amplifier having a cathode and a control electrode, a vacuum tube detector coupled to said amplifier, said detector having an output electrode, means for maintaining said output electrode normally negative relative to at least part of said amplifier cathode, means for causing said output electrode to become more negative in the presence of an amplified signal, and a direct-current connection between said control electrode and said output electrode, whereby the amplification of said amplifier is regulated automatically.

Sub C^2

1 w C

2. In a carrier-current signaling system, in combination, a vacuum tube amplifier having a cathode and a control electrode, a vacuum tube detector [illegible] to the output of said amplifier, said detector having a cathode and an output electrode, means for [illegible] detector cathode at substantially the same [illegible] amplifier cathode, means for maintaining said [illegible] trode at a negative potential with respect to [illegible], means causing said output electrode [illegible] in the presence of an amplified signal, and a direct-current connection between said output electrode and said [illegible] electrode.

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3. A combination according to claim 2 in which the means for maintaining the detector output electrode at a negative potential with respect to said cathodes is a resistance connected between said output electrode and the detector cathode.

4. In a modulated carrier ~~current~~ signaling ~~system employing~~ receiver having a carrier-current frequency amplifier, [illegible] rectifier coupled to the output circuit of said amplifier which rectifier produces a modulated uni-directional voltage, a direct-current connection from said rectifier to an element of said amplifier [illegible] is regulated automatically [illegible] rectifier [illegible] a modulation [illegible] whereby the signal is further amplified [illegible] rectifier [illegible] a condenser in series [illegible] modulation [illegible] amplifier.

Sub C. 4

5. [illegible] amplifier having a cathode [illegible] coupled to said amplifier, [illegible] means for [illegible] negative [illegible] a direct-current [illegible] said [illegible].

6. In a signaling system a vacuum tube amplifier having a cathode and a control electrode, a second vacuum tube having an output electrode, means for coupling the output of said amplifier with said second tube, means for maintaining said output electrode normally slightly negative relative to at least part of said cathode, means for causing said output electrode to become more negative in the presence of an amplified signal, and a direct current connection between said control electrode and said output electrode, whereby the amplification of said amplifier is regulated automatically.

7. In a receiving system, a vacuum tube amplifier having ~~an anode~~, a cathode and a control electrode, ~~a detector coupled to said amplifier, said detector having an output~~ [illegible] means for maintaining [illegible] ~~electrode normally negative~~ relative to at least part of said amplifier [illegible] ~~means for causing said output electrode to become more negative~~, [illegible] amplified signal, ~~a tuning arrangement for tuning said amplifier to a desired signal~~, [illegible] between said control electrode [illegible] whereby the amplification of said amplifier is regulated automatically [illegible] ~~condition of~~ [illegible] ~~in said tuning arrangement~~, whereby tuning is facilitated.

Insert B[7]
Insert B[8]

11. In a ~~signaling system a~~ vacuum tube ~~amplifier~~ having a cathode and a control electrode, ~~a~~ second vacuum tube having an output electrode, ~~means for coupling said amplifier with said second tube,~~ means for maintaining said output electrode normally [illegible] negative relative to at least part of said cathode, and including [illegible] means for causing said output electrode to become more positive [illegible] ~~of an amplified signal~~ [illegible] ~~said amplifier to a desired signal~~ [illegible] connection ~~between said control electrode~~ [illegible] electrode, whereby [illegible] ~~regulated~~ automatically, and [illegible] the condition of [illegible] whereby tuning is facilitated.

B
Sub C[3]
Insert B[10]

Re 12

12. In a radio-receiver, an antenna circuit for intercepting modulated-carrier signals of a wide range of amplitude and frequency, a radio-frequency amplifier including at least one [illegible] amplifier [illegible] at least one circuit tunable over said frequency range for selecting any desired signal [illegible] from said antenna circuit, said amplifier [illegible] a mutual-electrode [illegible] [illegible]

Per B
Insert B[16]
Per B
" B
" B
Ins C[6]
Per B
Per C[2]
Insert B

17. In a modulated-carrier signal receiver, ~~a~~ having carrier-frequency amplifier ~~including~~ [illegible]

~~tube for amplifying a desired signal,~~ [illegible]

and [illegible] that [illegible] combination

tube ~~[illegible]~~ [illegible]

decrease

~~[illegible]~~ [illegible]

negative bias ~~varied~~ [illegible] electrodes, [illegible]

vacuum tube [illegible] electrode [illegible]

signals [illegible]

electrode [illegible]

resistance for [illegible]

negative relative [illegible]

and increasingly negative with

~~[illegible]~~

~~[illegible]~~

~~[illegible]~~

[illegible]

[illegible]

[illegible] direct current [illegible]

[illegible]

Insert B[15]

[illegible] ~~wide range of~~

[illegible] frequency amplifier

[illegible] ~~range for~~

[illegible] ~~said antenna~~

[illegible]

15. In a modulated-carrier signal receiver, a carrier-frequency amplifier which includes ~~including~~ at least one ~~vacuum tube for amplifying a desired signal~~, said amplifier vacuum tube having a cathode and ~~having~~ a control electrode and proportioned so that its amplification decreases ~~for reducing the amplification of said tube with increasing~~ negative biasing potential ~~voltage~~ of said control electrode, a ~~diode detector having a cathode and an anode with resistance connected therebetween~~, means including [illegible] maintaining said [illegible] positive [illegible] at least part of said amplifier cathodes, and [illegible] ~~means for coupling the amplified signal output from said amplifier to said detector and thereby causing~~ the average [illegible] ~~anode to become~~ more positive, with ~~in response to~~ [illegible] amplified signal output from said amplifier, a direct-current connection from said anode [illegible] amplifier control electrode for impressing thereon a negative biasing potential ~~voltage~~ which varies [illegible] potential ~~voltage~~ [illegible] anode, [illegible] cathode and [illegible] in said direct current connection [illegible] ~~[illegible]~~ ~~[illegible]~~ [illegible] signal [illegible] ~~[illegible]~~ [illegible] increases [illegible]

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15. In a modulated-carrier signal receiver, a *having* carrier-frequency amplifier ~~including~~ at least one ~~vacuum tube~~ for amplifying a desired signal, ~~said~~ amplifier vacuum tube having a cathode and having a control electrode ~~for reducing~~ the amplification in said tube with increasing negative biasing ~~voltage~~ *potential* on said control electrode, a ~~diode detector~~ having a cathode and an anode with resistance connected therebetween, means for maintaining ~~said~~ *the* amplifier and ~~detector~~ cathodes at substantially the same potential, *the average pot* means including said resistance for maintaining said anode normally negative relative to at least part of said amplifier cathode, ~~means~~ for coupling ~~the amplified signal output from said amplifier to said detector and thereby causing the average voltage of said anode to become more~~ negative in response to increasing amplified signal output from said amplifier, a direct-current connection from said anode back to said amplifier control electrode for impressing thereon a negative biasing ~~voltage~~ which varies in accordance with the average ~~voltage~~ of said anode, a condenser connected between said amplifier cathode and a point in said direct- *in said direct current connection* current connection, and resistance between said point and said anode ~~in said direct-current connection~~ which with said condenser provides a time constant predetermined to [illegible] fluctuations at frequencies of ~~modulation~~ of ~~said amplified signal~~ output, whereby the carrier-frequency amplification [illegible] substantially *decreased* ~~reduced~~ [illegible] with increased amplified signal output from said amplifier.

Per B — 17. In a modulated-carrier signal receiver having a ~~, a~~
" B — carrier-frequency amplifier which includes ~~including~~ at least one ~~vacuum~~
" B — ~~tube for amplifying a desired signal, said~~ amplifier vacuum
B — tube having a cathode and ~~having~~ a control electrode and possessing the property that its amplification decreases ~~for~~
. B — ~~reducing the amplification in said tube~~ with increasing by
" B — negative biasing potential ~~voltage~~ on said control electrode, ~~a diode~~
Insert 13'a — 13'a ~~detector having a cathode and an anode with resistance con-~~
~~nected therebetween,~~ means including said resistance for
Per B — maintaining the average potential of said anode normally negative relative to at
" B — least part of said amplifier cathode and increasingly [illegible] ~~, means for coupling~~
. B — ~~the amplified signal output from said amplifier to said~~
" B — detector ~~and thereby causing the average voltage of said~~
" B — ~~anode to become more~~ negative, ~~in response~~ to increasing
. B — amplified signal output from said carrier-frequency amplifier, a direct-
current connection from said anode back to said amplifier
control electrode for impressing thereon a negative biasing
" B — potential ~~voltage~~ which varies in accordance with the average potential ~~voltage~~
of said anode, a condenser connected between said amplifier
cathode and a point on said direct-current connection,
" B — and said direct-current connection [illegible]
resistance between said point and said anode ~~in said direct-~~
" B — ~~current connection~~ which with said condenser provides a time
constant predetermined to filter out voltage fluctuations at
" — carrier [illegible] frequencies of modulation ~~of said amplified signal output~~, a
Insert — modulation-~~current~~ connection from said anode to a modulation-
" B — frequency [illegible] ~~current~~ amplifier, ~~through which the signal is further~~
" — ~~amplified and reproduced~~, and manually adjustable means for
B — determining the ~~amount of said further amplification~~, ~~whereby~~
. B — ~~the carrier-frequency amplification in said amplifier~~ is
. B — ~~substantially reduced automatically with increasing amplified~~
" B — ~~signal~~ output from said amplifier and the reproduced signal
" — is thereby maintained substantially at the volume determined
B — ~~by said adjustable means~~.

Sept. 27, 1932. H. A. WHEELER 1,879,863

VOLUME CONTROL

Original Filed July 7, 1927 4 Sheets-Sheet 1

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BY

ATTORNEY

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VOLUME CONTROL

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Sheet 4

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Patented Sept. 27, 1932 1,879,863

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VOLUME CONTROL

Original application filed July 7, 1927, Serial No. 203,879, and in Great Britain July 3, 1928. Divided and this application filed November 13, 1930. Serial No. 495,386.

Pg. 1, Col. 1.

This invention relates to amplifiers, and more particularly to amplifiers utilized in modulated carrier-current signaling systems wherein the limit of amplification is automatically maintained substantially at a predetermined level.

This application is a division of application Serial No. 203,879, filed July 7, 1927.

When amplifiers are employed for amplifying a signal voltage it becomes desirable for various reasons to control automatically the amplitude of the amplified signal voltage. To this end the present invention provides means for effecting automatic amplification control. Such an arrangement, for example, is particularly advantageous in radio receivers such as are employed for receiving broadcast signals, because it prevents the overloading of the last amplifier stage of the receiver, which overloading would result in distortion of the reproduced signal, as well as loud and harsh reproduction.

Another advantage resides in uniform reproduction of the amplified signal irrespective of whether the carrier current is received from a nearby station or from a distant or a high power station or a low power station, since it has been found in former radio receivers that when the receiver was reproducing strong signals, as from a nearby or a high power station, [illegible] reproduced signal [illegible] signal was received from [illegible] power station, it was [illegible] with the result that [illegible] reproduced [illegible] from [illegible] distant stations and from [illegible] power stations it became [illegible] to readjust some volume control [illegible] the receiver to compensate for these signals.

It has also been [illegible] the use of former radio [illegible] produced signal was [illegible] phenomenon of fading [illegible] ceived signal [illegible] came much weaker [illegible] point of inaudibility [illegible] vention provides an arrangement which automatically compensates for [illegible]

F[illegible]

Pg. 1, Col. 2.

received carrier-current signal strength, when "fading" takes place the degree of amplification is correspondingly increased and the reproduced signal maintained at its former volume, so that a listener is unaware that variation of the received carrier current signal is occurring. This automatic compensation for signal fading is especially advantageous in commercial radio telephony and file systems.

~~In existing radio receivers in which operat-~~ ing current is derived from the main [illegible] power system, it has been found that when there is considerable variation in the line voltage supply, the volume of the reproduced signal is not uniform. An additional advantage of the present invention is that of automatically compensating for such line voltage variations with the result that the ~~reproduced signal is uniform in volume.~~

A still further advantage is the saving in plate current which is automatically effected during the reception of powerful signals for the reason that the invention incidentally provides means for reducing the plate current of one or more amplifying tubes as the signal strength increases.

Fig. 1 is a circuit diagram of a complete radio receiver which includes the present invention and consists of a three-stage radio-frequency amplifier followed by a rectifier, a two-stage audio-frequency amplifier, and a loud speaker or other suitable indicating device.

Fig. 2 shows curves illustrating the relation between the radio-frequency [illegible] and the audio-frequency [illegible] with and without the application of the present system.

Fig. 3 [illegible]

[illegible]

~~Fig. [illegible]~~ [illegible]

[illegible]

Pp. 2, Col. 1.

~~may be substituted for the corresponding ele-~~ ments inclosed in the dotted rectangle of Fig. 1.

Fig. 6 shows a diagrammatic arrangement of a radio receiver incorporating the present invention, and operated entirely from a rectified and filtered alternating source of current, thus eliminating the "A", "B" and "C" batteries now so widely used.

Fig. 7 is a circuit diagram of a radio receiver in which several of the features of the present invention are combined in a single ~~embodiment~~.

Fig. 8 shows graphically a comparison between the performance of the two-electrode valve or rectifier, and of the three electrode detector.

Referring in detail to Fig. 1, there is shown an antenna 5 connected to ground 1 through the primary winding 6 of a radio frequency transformer, the secondary winding 7 of which, tuned by a variable condenser 8, is connected at one point to the filament of the vacuum tube 9 in the first radio frequency amplifying stage and at another point to the grid 11 of this vacuum tube. The output circuit of this vacuum tube extends from the filament system, through a high voltage battery "B", a milliammeter 16, primary winding 17 of a second radio frequency transformer to the anode or plate 14 of this vacuum tube. In order to neutralize the inherent capacity between the grid 11 and the plate 14, and thereby to prevent oscillations, and otherwise to increase the effectiveness of the present invention as hereinafter described, a neutralizing winding 19, electromagnetically coupled to winding 18, and a neutralizing condenser [illegible] are employed in the manner described in the U. S. patents to Hazeltine Nos. 1,450,[illegible] and 1,[illegible].

A second stage of radio frequency amplification including the vacuum tube 16 is neutralized by cooperation of coil 26 and condenser [illegible]. Like the first stage, comprises the secondary winding [illegible] of the last mentioned radio frequency transformer tuned by a variable condenser [illegible] the filament system of the vacuum tube [illegible] and the grid [illegible] thereof. The output circuit of the vacuum tube [illegible] the high voltage battery "B" and a primary winding [illegible] radio frequency transformer, [illegible] secondary winding [illegible] by a variable condenser [illegible] input circuit of a third stage of radio frequency amplification [illegible] tube 23. The inherent capacity [illegible] tween the electrodes [illegible] by a network including the neutralizing condenser 28 and the neutralizing winding [illegible] described in the [illegible] put circuit of [illegible] primary winding [illegible] cy transformer [illegible] high voltage battery "B". The secondary winding [illegible]

Pg. 2, Col. 2.

mentioned transformer, tuned by a variable condenser 32, is connected in the input circuit of a rectifier 33 which input circuit includes the fixed condenser 2. The rectifier employed may be of the type commonly known in the art as a two-electrode "Fleming" valve, or may consist of an equivalent such as a three-electrode vacuum tube, as shown, having its grid 12 and its plate or anode 35 directly connected together to comprise in effect a single anode.

It may here be noted that throughout the present specification and claims the terms "rectifier" and "detector" are, in general, used interchangeably, the terms "rectifying" and "converting" being employed in the general sense to include the process of changing alternating current into a form of direct current or modulated unidirectional current. Likewise, the terms "carrier-current" and "modulation current" may be substituted, respectively, for "radio frequency current" and "audio-frequency current", since the description herein of radio frequency amplifiers and audio frequency amplifiers is merely by way of example of a typical embodiment of the present invention.

In the absence of the present invention including the control circuit 36, to be described, the three-stage amplifier functions in a manner well known in the art to amplify the incoming signal intercepted on the antenna 5. The output circuit of the rectifier 33 includes what may be termed a "rejector" circuit for stopping radio frequency currents which have passed through the rectifier, and consists of a network including a resistance 34 and a by-pass condenser 37 connected between the anode 35 and the filament 38 of the rectifier. The output circuit of the rectifier is coupled to the input circuit of an audio frequency amplifying vacuum tube [illegible] through an audio frequency pass filter including a fixed condenser 40 and an impedance 41 connected between the filament 42 and the grid 43 of this vacuum tube. The output circuit of this amplifier is connected between the filament 42 and plate 44 through the high voltage battery "B" and the primary winding 45 of an audio frequency transformer, the secondary winding 46 of which is connected in the input circuit of a second audio frequency tube 47, while a resistance 48 connected across the winding 46 serves to give the audio amplifier substantially uniform amplification over the desired frequency range. Instead of employing resistance 48, a closed copper band of suitable size may be placed around the transformer winding so as to be electromagnetically coupled thereto. A loud speaker or other reproducing device 50, or if required, a coupling device for a telephone system, is connected in the output circuit of the last audio-frequency amplifying tube 47. It is presumed that adequate pre-

through [illegible] filter the audio-frequency [illegible] is transferred to the input circuit of the audio or modulation-frequency amplifier, while preventing the unidirectional component from being impressed upon the input circuit thereof. (from original claim 4).

Exhibit A (p. 8).

Pg. 3, Col. 1.

cautions against undesired electromagnetic coupling between the various radio-frequency coupling transformers are included in all of the arrangements herein disclosed.

In accordance with the main feature of the present invention, means are provided to control automatically the degree of amplification effected in the radio-frequency amplifying stages. These means include a resistance 51, connected between the filament 38 and the anode 35 of the rectifier, through which the pulsating rectified or converted current flows, thereby developing a negative voltage at terminal 52. This negative voltage is applied over conductor 36 through the ~~impedance~~ 53 and the secondary winding 7 of the first radio-frequency transformer to grid 11 of the first radio-frequency stage. ~~Impedance~~ 53, together with blocking condenser 54, is effective to filter out and reject any audio frequency currents which otherwise might be present in the conductor 36.

To complete the description of the system illustrated in Fig. 1 certain design data or constants are given herewith. It should be understood, however, that these, as well as all other constants appearing in the present specification are mentioned merely by way of example in describing certain specific embodiments which in practice have proved eminently satisfactory, and are not intended to suggest any specific limitations as to the scope of this invention. Accordingly, fixed condensers 2 may be of 0.0005 microfarads; 37 of 0.0001 microfarads; 54 of 0.01 microfarads; 40 of 0.006 microfarads; resistance 51 of 1 megohm; 24 of 1 megohm; and 41 and 53 of 2 megohms each.

The tubes may be assumed to be all of the well known 201A type. (Amend [illegible])

Exhibit A [illegible]

The high resistance 51 connected between the filament 38 and the anode 35 of the rectifier, through which a small space current flows in the absence of signal output from the radio-frequency amplifier, maintains the anode normally negative relative to at least part of the filament of the rectifier. Since all the filaments are connected in parallel, the rectifier filament is maintained at substantially the same potential as the filament 27 of the first radio-frequency amplifier tube 9. Therefore the resistance 51 is connected effectively between the rectifier anode 35 and the amplifier filament 27, and thereby maintains the rectifier anode normally negative relative to at least part of the amplifier filament. (From original claim 11.)

Pg. 3, Col. 1.

In the operation of the receiver shown in Fig. 1 a signal intercepted on the antenna 5 is successively amplified through the neutralized radio frequency [illegible] by the vacuum tubes 9, 15 and [illegible]. This amplified signal voltage is then rectified by the rectifier [illegible] and the rectified pulsating current is successively amplified by the audio amplifying stages including vacuum tubes [illegible] and 17, after which it may be reproduced as sound by the loud speaker [illegible]. When the rectified or converted signal current flowing through the resistance 51 [illegible] a predetermined value, there is developed at the terminal 52 sufficient negative biasing voltage, which in turn is impressed through the conductor 36, upon the grid 11 of the [illegible] tube 9 [illegible] the amplification [illegible] tube. It will be apparent that as the magnitude of the rectified current through the resistance 51 increases with [illegible] the voltage at terminal 52 [illegible] tive, and the negative biasing voltage impressed upon the grid 11 [illegible] that the vacuum tube 9 effects [illegible] degree of amplification. In [illegible] radio frequency voltage applied to the input

Pg. 3, Col. 2.

of the rectifier is maintained at a nearly constant predetermined value, and the volume of the reproduced signal is substantially uniform under all conditions. The degree of volume of the reproduced signal is then determined by adjustment of rheostat 49 which controls the heating current in the filament 42 of the first audio-frequency amplifying tube 39. The neutralization of the grid-plate capacity of the radio-frequency amplifying tubes is, in combination with the present invention, particularly valuable in that it allows an increase in the effectiveness of the amplification control, because such neutralization prevents radio-frequency energy from passing through the grid-plate capacity of the tubes. Thus the relay action of the tubes is almost entirely subject to the control by grid bias voltage provided in accordance with this invention.

The time required for operation of the control system would ordinarily be determined by the lowest audio-frequency modulation which must be reproduced. Fading, for example, might be considered a form of modulation; the frequency of the rise and fall of signals due to fading being the frequency of modulation. If this frequency of modulation be increased sufficiently, the effect will be audio-frequency modulation. It will thus be seen that if the automatic control attained by the present invention be allowed to respond too quickly, it will tend to smooth out the desired modulation of the signal at the lower audio frequencies. Hence, a time constant of operation is chosen which will be greater than the period of the audio frequencies which the system is intended to amplify. This time constant of the control circuit is equal to the product of the series resistance and the shunt capacitance of the grid bias circuit, represented in Fig. 1 by [illegible] ~~[illegible]~~ 31 ~~[illegible]~~ 32 [illegible] the time constant [illegible] be reduced [illegible] to the period of the lowest modulation frequency, it may readily be set to meet the requirements of nearly any special case which may arise. For example, a value of two million ohms resistance and of 0.1 microfarad capacitance gives a time constant of one-fifth of a second, which does not appreciably affect the modulation of frequencies above five cycles. While this constant is greater than required from the point of view of satisfactory audio-frequency quality in the reproduction of music, there appears to be no need for more rapid control under the conditions usually encountered. The use in this connection of capacities of large [illegible], such as one-tenth microfarad, [illegible] introduces another convenience in that the condensers may also serve to by-pass radio frequencies in order to prevent undesired coupling between the detector circuit and the first radio-frequency amplifying tube because of some impedances

on the arbitrary standard [illegible] used by [illegible]

¶ In the above operation it is noted that the two-electrode rectifier 33 functions as the detector and also effects rectification of the radio-frequency carrier current to control amplification in the first radio-frequency stage of the receiver. The audio-frequency component of the detector output is transferred to the input circuit of the audio-frequency amplifier for further amplification.

(From P. 4, ls. 113-117, and original claim 4).

between [illegible] 36 and the anode terminal 52 in the direct-current connection back to the grid 11,

[illegible] filament 27 [illegible] rectifier 33.

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common to those two portions of the apparatus.

For a better understanding of the present invention reference is made to Fig. 2, ~~from which it~~ will be appreciated that in a system similar to that illustrated in Fig. 1, but in which no means for automatically limiting the degree of amplification is included, the amplified radio-frequency voltage is proportional to the radio-frequency antenna voltage, as indicated by curve 102. When, however, the present invention is employed in such an amplifier, the relation between the radio-frequency antenna voltage and the amplified radio-frequency voltage is indicated by curve 103 from which it will be seen that when at least a certain predetermined radio-frequency antenna voltage is present, (herein referred to as the "threshold antenna voltage") the amplified radio-frequency voltage approaches—but is always less than—another certain predetermined voltage value (herein referred to as the "cut-off voltage").

The modification illustrated in Fig. 3 is an especially desirable form of the present invention, and includes antenna 56, connected by means of a transformer 57 to a neutralized three stage tuned radio-frequency cascade amplifier including the vacuum tubes 58, 60 and 62 coupled by transformers 59 and 61. The last stage of the amplifier is connected by a transformer 63 to a two-electrode rectifier 64 of the type already described, the output circuit of which, including the resistance 65, is connected between the anode 66 and filament 67 of the rectifier, as previously explained. Resistance 72 and condenser 68 associated with this output circuit, constitute a "rejector" network which filters out the radio-frequency current component in the output circuit of the rectifier 64, while the network including condenser 69 and resistance 70 constitutes an audio-frequency pass filter for coupling the output circuit of the rectifier to the input circuit of the audio-frequency amplifier which includes vacuum tube 71. Rheostat 73 controls the heating current supplied to the filament 74 of this vacuum tube, and thereby permits a manual adjustment of the volume of the reproduced signal desired by the listener. Audio frequency transformer 76, which is preferably of a low ratio of transformation, couples the output circuit of vacuum tube 71 to a second audio-frequency amplifying tube 77. This last vacuum tube in turn is coupled by a second audio-frequency transformer 78 to a third audio-frequency amplifying tube 79 in the output circuit of which there is included a loud speaker 8[illegible].

In this arrangement automatic amplification control is effected in a manner slightly different from that shown in the diagram of Fig. 1, since in this instance the radio-frequency voltage of the signals intercepted by the antenna 56 is successively amplified

The milliammeter 10 is connected in the anode circuit of the amplifying vacuum tube 9. Upon receipt of an amplified signal at the detector, the effect of the control circuit is to decrease the plate current through milliammeter 10, thereby reducing the amplification in the tube 9. When the receiver is tuned to the signal frequency, a minimum amplification is required, so that when the condition of resonance is attained, the plate current of tube 9 is at a minimum value, and the milliammeter 10 so indicates. Thus the milliammeter visually indicates the condition of resonance.
(From original claims 6, 7, 12, and p. 5 ls. 85-94).

Exhibit A (p 12)

Pg. 4, Col. 2.

by three neutralized tuned radio-frequency amplifying stages including the vacuum tubes 58, 60 and 62, of which two are controlled in accordance with the present invention. The amplified radio-frequency current is rectified by the rectifying valve 64, and successively amplified at audio-frequency by the vacuum tubes 71, 77 and 79. The rectified current in the output circuit of the rectifier flows through the resistance 65, and thereby develops a negative voltage at the terminal 81, which voltage is applied through the ~~impedances~~ 72, 82, 83 and 85 to the grids 84 and 86 of the radio-frequency amplifying tubes 58 and 60. By thus simultaneously controlling the degree of amplification of two successive radio-frequency amplifying stages a greatly increased uniformity of regulation is attained. ~~Impedance~~ 82 and the condenser 87 constitute an audio-frequency stop filter, so that substantially only direct voltage is impressed upon the grids 84 and 86. It will be understood that the voltage developed at terminal 81 is a function of the amplified radio-frequency voltage delivered to the input circuit of the rectifier by the radio-frequency amplifying tubes 58, 60 and 62, and therefore, as the negative voltage at terminal 81 tends to increase with the increased signal, the resulting increase of biasing voltage impressed upon the grids of the tubes 58 and 60 limits the degree of amplification effected in the radio-frequency stages including those tubes.

In this arrangement the constants for the various resistances and condensers may, for example, be the same as those for the corresponding elements in Fig. 1. In addition the grid resistances 83 and 85 may have a value of 2 megohms each, and the grid condensers connected at the junction of these resistances and the grid electrodes 84 and 86 may each be of 0.001 microfarad capacity.

~~The modification shown in Fig. 4 differs~~ from the arrangement of Figs. 1 and 3 mainly in that it employs a three-electrode vacuum tube which functions in the manner of the well-known three-electrode detector, and also effects rectification, or conversion, of the radio-frequency carrier current to control amplification in the first radio-frequency stage of the receiver. As in the preceding arrangements, there is here employed an antenna or other suitable signal interceptor 88 coupled by means of a radio-frequency transformer 89 to a two-stage neutralized tuned radio-frequency amplifier including the vacuum tubes 90 and 91 coupled by means of a radio frequency transformer 92. The output circuit of the last stage of the amplifier is connected by means of radio-frequency transformer 93 to the tuned input circuit of a three-electrode vacuum tube detector 94, which input circuit is tuned by the inductance ~~of the secondary winding of trans-~~

In [illegible] 1 and [illegible] [illegible] grounded in [illegible] [illegible] [illegible] fects as well as [illegible] practi[illegible] condensers in a single unit for uni-control, [illegible]. (From p. 7, ls. 2[illegible]).

Exhibit A. (p 13)

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former 99 in shunt to variable condenser 95. A suitable negative voltage is maintained on the grid 96 of the detector tube, through the secondary winding of transformer 93, by "C" battery 97 and by potentiometer 98 connected across the filament of the detector tube. By means of this potentiometer connection, a negative voltage may be applied to the grid 96 varying from one volt to a maximum of five volts; the minimum value being the difference between the six volts of "C" battery 97 and the voltage drop across the filament of the detector. The output circuit of the detector includes the primary winding of transformer 99, a 45 volt battery 100 and a 500,000 ohm resistor 101, connected in series between the anode of the detector and the common "B" battery. A fixed condenser 104 by-passes the radio-frequency current that has passed through the detector, while the audio-frequency component of the rectified, or converted, current is transferred through the audio-frequency transformer 99 to the input circuit of an audio-frequency amplifying vacuum tube 105, the filament circuit of which includes rheostat 106 for controlling the arbitrary volume level of the amplified signals. The output circuit of the audio-frequency amplifier 105 is coupled by means of an audio-frequency transformer 107 to the input circuit of a second audio-frequency amplifying tube 108. The output circuit of this vacuum tube includes the usual loud speaker or indicating device 109. A resistance 110 is connected across the secondary winding of transformer 107 to secure substantially constant amplification within the frequency range of the audio-frequency amplifier, especially when the plate resistance of the preceding tube 105 is high as a result of the adjustment of rheostat 106.

For controlling the amplitude of the radio-frequency voltage applied to the input circuit of detector 94, a conductor 111 is connected at point 112 common to a terminal of resistor 101 and battery 100, and thence through the secondary winding of transformer 89 to the grid of the first radio-frequency amplifying tube 90. A by-pass condenser 113 connecting the conductor 111 to the filament system serves to filter out and reject any audio-frequency currents present in the circuit including the conductor 111, thereby insuring that these currents have no effect on the grid of the vacuum tube 90. Battery 100 is the source of negative biasing voltage applied to the control grid, or control electrode, of the radio-frequency amplifying tube, this battery being so connected to the output circuit of the detector, or rectifier, that fluctuations of voltage in the detector output circuit cause equal fluctuations in the negative biasing voltage impressed upon the control grid.

In this embodiment, condensers 104 and 113 may be of 0.0005 microfarad and 1 microfarad capacity, respectively, while resistance 101 may have a value of 0.5 megohm.

In adjusting the receiver of Fig. 4, it is necessary to determine the correct setting of the detector grid potentiometer 98. This adjustment should be made while there is no signal being received, as follows. First, the switch 115 is closed, and the normal plate current of the tube 90 is noted on milliammeter 116. Then the switch is opened, thus placing the control circuit in operation. In general, the plate current of vacuum tube 90 will change when the switch is opened, since the grid voltage of this tube is dependent upon the control circuit. By varying the grid voltage of the detector by potentiometer 98, the plate current of tube 90 is then adjusted to the normal value, and the apparatus is ready for operation. Upon receipt of an amplified signal at the detector, the effect of the control circuit is to decrease the plate current through milliammeter 116, thereby reducing the amplification of the tube 90. When the receiver is tuned to the signal frequency, a minimum amplification is required, so that when the condition of resonance is attained, the plate current of tube 90 is at a minimum value.

It is believed unnecessary to explain the operation of the two radio-frequency amplification stages and of the detector, or of the two audio-frequency amplification stages, for in operation they are substantially similar to those of the now well known type of radio receiver employing neutralized two-stage radio-frequency and two-stage audio-frequency amplifiers. The control circuit operates, in the arrangement of Fig. 4, substantially in the same manner as in Figs. 1 and 3, to apply a negative biasing voltage to the grid of the radio-frequency amplifying vacuum tube 90, this voltage being a function of the radio-frequency voltage which has been amplified by the vacuum tubes 90 and 91 and then applied to the input circuit of detector 94. Since the voltage applied over conductor 111 is a function of the amplified radio-frequency voltage, there is a maximum or cut-off detector voltage determined by the constants of the circuit, as shown in Fig. 2, beyond which the radio-frequency amplifier is prevented from effecting further amplification. This arrangement maintains the finally amplified radio-frequency voltage at substantially constant value.

Fig. 5 shows an alternative system for coupling the detector to the first audio-frequency amplifying tube of Fig. 4. The coupling arrangement of Fig. 5 included within the dotted rectangle, when substituted for the corresponding portion enclosed within the rectangle of Fig. 4, provides a modified form of the invention. Corresponding elements of these two figures are identified by the same

~~reference characters, from which it will be~~ seen that Fig. 5 differs from Fig. 4 in that the transformer coupling between the detector 94 and the first audio-frequency amplifying tube 105 has been replaced by an impedance coupling arrangement including the condenser 117 and the impedance 118.

While this modification does not utilize a transformer having a step-up ratio such as is included in the arrangement of the former figure, it, nevertheless, introduces the advantage of effecting a more nearly constant degree of amplification at audio frequencies. When the modification of Fig. 5 is substituted in the system of Fig. 4, as described, the values of elements 104 and 101 may be the same as mentioned above; the resistance connected in lead 111 may be of 2 megohms; 118 of 2 megohms; 117 of 0.005 microfarad; and 113 of 0.5 microfarad.

Referring to Fig. 6, there is shown a radio receiver of the unneutralized type in which the so-called "A", "B" and "C" batteries have been replaced by a source of rectified and filtered alternating current. In this embodiment of the invention there are provided three stages of tuned radio frequency amplification in which the vacuum tubes of the successive stages are designated 119, 120 and 121, respectively. These several stages are transformer coupled, and the last stage of the amplifier is coupled to a three-electrode vacuum tube detector 122, the grid bias voltage of which is controlled by potentiometer 128. In the output circuit of detector 122, there is provided a "rejector" circuit, similar to that previously described, for filtering out radio frequency currents that have passed through the detector; and also an audio frequency network, or impedance coupling, including condenser 123 and impedance 124, for passing the audio frequency component of the rectified signal to the first audio frequency amplifying vacuum tube 125. The filament of this tube is shunted by rheostat 129 which functions as a manual volume control. This last tube is transformer coupled to a second stage of audio frequency amplification, including the vacuum tube 126, in the output circuit of which there is provided a loud speaker, or other suitable indicating device, 127, which on occasion may be replaced by a coupling device to a telephone system. The filaments of these six vacuum tubes are connected in series across a suitable resistance in the rectified filtered source of power supply, giving a potential difference of 30 volts, thus taking the place of an "A" battery. The necessary "C" or bias, voltage is derived from a potential difference across a resistance in that portion of the power supply indicated by the reference character "C", while the plate current supply is similarly derived from a resistance ~~in that portion of the power supply indicat-~~ ~~ed by the reference letter, "B".~~ It should be noted that the filament of the first radio-frequency amplifying tube 119 is connected to the positive terminal of the 30-volt "A" section of the power source, and that the filament of the detector tube 122 is connected to the negative terminal of this section. The constants of the elements of this embodiment may in general be similar to those suggested with reference to Fig. 5.

In adjusting the receiver of Fig. 6, the potentiometer 128 is adjusted with switch 115 open, as described in connection with the adjustment of the receiver of Fig. 4. This arrangement with the vacuum tube filaments connected in series obviates the necessity of a separate battery corresponding to 100 of Figs. 4 and 5, since the plate of the detector tube 122 can be positive relative to the filament of that tube, and at the same time maintains the grid of the first radio frequency amplifying tube 119 negative relative to the filament of the same tube, due to the difference of potential between the two filaments. Thus the biasing voltage applied to the control grid is derived from the voltage across the filaments instead of from a battery as in Figs. 4 and 5.

In Figs. 4 and 5, batteries "B" and 100 are connected in series in the plate circuit of detector 94 and both contribute to the detector plate current. The "B" battery supplies the voltage drop in resistor 101, while battery 100 supplies the plate voltage of detector 94. The presence in the detector plate circuit of the "B" battery, which is directly connected to the grounded filament circuit, in addition to auxiliary battery 100, allows the use of a high impedance 101 in the detector plate circuit with a resulting high sensitivity of the detector circuit. The same result is achieved in the arrangement of Fig. 6 by the combination of the "A" and "B" voltages in the detector plate circuit, as described before. In the event that tubes having an indirectly heated cathode are used instead of those having an incandescent filament cathode as represented in the figure, the same advantages may be obtained as pointed out in connection with Fig. 6, if the detector cathode is maintained at a potential much more negative than the cathode of the controlled tube or tubes, which in the figure is the first radio frequency amplifier tube.

The circuit arrangement shown in Fig. 7 incorporates several advantages obtained by the present invention, some of which have been more or less described above. Briefly, this arrangement includes a combination of the features illustrated in and described in connection with Fig. 3 and Fig. 6. The reference characters of Fig. 7 correspond to those employed in Fig. 6 and have the same significance. It will be noted in addition to ~~the apparatus represented in Fig. 3, that~~

~~there has been illustrated a power unit of rec-~~ tified and filtered alternating current which replaces the so-called "A" and "B" batteries represented in Fig. 5, and in addition, includes a source of "C" or grid bias voltage for tube 79. The grid of tube 77 is biased by connecting the "grid return lead" to an appropriate point in the series filament circuit, as shown. The power source is similar to that shown in and described in connection with Fig. 6. The present arrangement thus includes the advantages of neutralized radio frequency amplifying stages, automatic volume control applied to the first two stages of the radio frequency amplifier, a two electrode valve or rectifier and the complete elimination of all batteries for supplying operating potentials to the system. As is also true of the arrangement of Fig. 6, the automatic volume control not only compensates for the variations in the strength of the incoming signal but also compensates for reasonable variations in line voltage of the alternating current power supply.

As in Fig. 6 the variable tuning condensers C_1—C_4 are grounded in order to eliminate undesirable capacity effects as well as to make it practicable to connect the condensers on a single shaft for uni-control, if desired. As in Fig. 6, it will be seen that the power supply of Fig. 7 is not grounded, thus eliminating the danger of short-circuiting the direct current supply when a separate ground is necessary for the alternating current rectifying and filtering system. In certain instances, Figs. 6 and 7 differ in the connection of certain by-pass condensers. The purposes and reasons for the positions of these by-pass condensers should be apparent to those skilled in the art.

Assuming that the vacuum tubes employed are of the type having five volt filaments, 35 volts of filament, or "A", supply is needed. As above mentioned, the automatic volume control is here applied to two tubes, namely 58 and 60; the cut-off being effected with the use of two different plate, or "B", voltages. The plate electrode 66 of rectifier 64 is more negative relative to the filament of tube 58 than relative to the filament of tube 60, by the 5 volt drop across one filament. To compensate for this difference, 5 volts higher "B" voltage is applied to the plate of tube 58 than to the plate of tube 60, which makes both tubes cut off practically at the same time. The reason for applying a "B" voltage of 85 volts (which, of course, is to be added to the 35 volts "A" voltage) to the plate of tube 60, whereas a "B" voltage of 90 volts is applied to the plates of the radio frequency amplifying tubes of Fig. 6 is that the arrangement of Fig. 7 employs one more tube than Fig. 6; the difference of 5 volts being included in the "A" supply, as will be seen ~~by comparing the two figures. Thus actu-~~ ~~ally, the plates of the radio frequency ampli-~~ fying tubes 119, 120 and 121 of Fig. 6 are provided with 90, 95 and 100 volts, respectively. Similarly the plates of the amplifying tubes of Fig. 7 are supplied with 85 to 105 volts.

In addition to the combined advantages just outlined, the arrangement of Fig. 7 also includes an additional feature which has not previously been described, namely, the means 130 for determining the filament current supplied to one of the amplifying tubes. As has been explained in connection with Fig. 6, when operating the filaments of the several vacuum tubes on rectified and filtered current from an alternating current power source, it is desirable that the filaments be connected in series since it is at present more practicable to provide a current supply at a comparatively high voltage and low current. Fig. 6 shows a shunt rheostat 129 connected in parallel with the filament of tube 125 so that the current divides between the rheostat and the filament. While this means for controlling the filament emission of a single tube, as shown in Fig. 6, is fairly satisfactory, the arrangement shown in Fig. 7 is a substantial improvement. With the former method, an increase in current through the controlled filament is accompanied by a smaller increase in current through the other filaments in series. The improved arrangement shown in Fig. 7, on the other hand, by providing three resistances, two of which are simultaneously variable, allows a variation of the voltage on one or more filaments without affecting the current through the other filaments or, more generally, without changing the load on the filament current supply. It is apparent that the benefits of this device will be especially manifest in an arrangement such as the present, wherein the current supply for the filaments is obtained from a rectified, filtered alternating current source, particularly when the rectifying device is of the common type without automatic voltage regulation. The compound rheostat 130 comprising resistances R_1 and R_2 is so arranged that a movement of the control knob will increase the one resistance, while diminishing the other in proportion. One of these resistances, namely R_1, is connected in series with resistance R_3 in shunt with filament 74 of tube 71, the resistance of filament 74 being represented by "R_f". It may here be pointed out that while Fig. 7 illustrates the manual control of the filament of only one tube, namely 74, the filaments of other tubes could be connected either in series or parallel with filament 74 if it were desired that independent simultaneous control be had of more than one filament. "R_f" may, therefore, be taken to represent the effective resistance of the filaments to be controlled. When the two ~~resistances R_1 and R_2 and the fixed resistance~~

Exhibit A (p. 10)

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~~R_8 are properly proportioned to the normal~~ operating resistance R_f of the filament or filaments of the tubes to be controlled, the resistance of the system as a whole will remain substantially constant during adjustment of the control device 130. By way of illustration, the following data are given for Fig. 7, assuming the tubes to be all of the well-known 201A type, each filament being of 20 ohms resistance: R_f will equal 20 ohms; R_6 may equal R_f; R_7 may equal $8R_f$; and R_8 may equal $\frac{1}{2}R_f$. Accordingly, to control one tube when R_f equals 20 ohms, R_6 will equal 20 ohms, R_7 will equal 160 ohms, and R_8, 10 ohms.

It is believed unnecessary to describe the method of controlling the signal amplification in the arrangements of Figs. 5, 6 and 7 since they are substantially similar in operation to that of the systems described in reference to Figs. 1, 3 and 4. It should be mentioned, however, that the advantages of the present invention are especially apparent in systems such as shown in Figs. 6 and 7, because of the fact that any reasonable fluctuations in the voltage of the power supply line are thus automatically compensated for, ~~and uniform volume of signals is secured.~~

There are advantages attending the use, in connection with the present invention, of the two-electrode rectifier circuit typified by Figs. 1, 3 ~~and 7,~~ which may not be apparent from the foregoing discussion. It is impossible to overload this type of rectifier, and the rectified output voltage is directly proportional to the applied alternating signal voltage when this voltage is large, say over two volts. The control system in the circuits of the figures referred to requires a large operating voltage, say ten volts, so that the latter condition of large signal voltage is realized. No such simple relationship is possible in a three-electrode detector, whose rectified output never exceeds a limiting upper value, and is never proportional to the applied voltage, except over a very small range of voltages. This distinction will be seen from Fig. 8 where the abscissae "A. C." represent the alternating signal voltages, whereas the ordinates "D. C." represent the rectified output voltages. It is well known that the linear curve is much more desirable when minimum distortion of a modulated signal is desired, and it will be observed from Fig. 8 that the preferred type of curve is obtained from the two-electrode rectifier.

~~A further advantage of the two-electrode~~ detector with the automatic volume control connection and a visual resonance indicator in the anode circuit of the amplifier whose grid bias is being automatically controlled lies in the fact that the visual resonance indicator will give an indication which is proportionate to the [illegible] ~~This follows from the fact that the [illegible]~~

Pg. 8, Col. 2.

~~grid bias on the amplifier is directly pro-~~ portional to ~~the~~ strength of the signal; and hence the anode current ~~bears~~ a similar rela- ~~tion to the signal.~~

A ~~The~~ three-electrode detector ~~is~~ would be useful for relatively small applied voltages, and the rectified output voltage ~~is~~ would then be approximately proportional to the square of the applied voltage, i. e., to the power associated with the applied voltage. For this reason the rectified voltage would ~~increases~~ increase with the carrier wave modulation. ~~When~~ If such a detector ~~is~~ were used in ~~the~~ an automatic amplification control system, ~~as in Figs. 4, 5 and 6,~~ the total power from the radio-frequency amplifier ~~is~~ would be maintained at a substantially constant level, the amplitude of the carrier wave being decreased in the presence of modulation. It is desirable to maintain the carrier wave at a constant amplitude at the output of the amplifier, and this is accomplished by the two-electrode rectifier as shown in Figs. 1 and 3 ~~and 7~~. The control system maintains constant the average signal amplitude which is equal to the carrier wave amplitude and independent of the degree of modulation.

It will be observed that in a system employing a two electrode rectifier such as represented by valve 33 of Fig. 1, and 64 of Fig. 3 ~~and 7~~, the control bias voltage is independent of the "B" or anode battery voltage. Since the rectifier is not an amplifier, is not critical, and requires neither anode nor biasing battery, no adjusting devices are required. ~~This is not the case in the three-electrode detector circuits, so that a potentiometer, 98 or 128 in Figs. 4 or 6, respectively, must be adjusted as described to accommodate the control bias to any particular combination of tubes and "B" voltage. On the other hand, the latter type of detector is more sensitive because it is also an amplifier, so that the control system operates on a smaller applied alternating voltage.~~

In the foregoing description, tuned radio-frequency receivers of the neutralized ~~and unneutralized~~ type have been referred to. It should be pointed out, however, that the present invention may be employed with equal effectiveness to any radio receivers in wired radio and space radio systems, and that it has been found especially applicable to receivers of the super-heterodyne type.

It is well known that the common "B" battery may be replaced by a source of rectified and filtered alternating current, and, in the event that tubes having indirectly heated cathodes are used instead of those having incandescent filament cathodes, the common "A" battery may be replaced by a source of alternating current.

¶ For ~~this~~ these reasons the present disclosure of typical embodiments of the invention should not be construed as a limitation, but merely as illustrative of the principles of the invention, the scope of which is defined in the appended claims.

What is claimed is:

1. In a signaling system a vacuum tube amplifier having a cathode and a control electrode, a vacuum tube detector coupled to said amplifier, said detector having an output electrode, means for maintaining said out-

Exhibit A (A-5)

put electrode normally negative relative to at least part of said amplifier cathode, means for causing said output electrode to become more negative in the presence of an amplified signal, and a direct-current connection between said control electrode and said output electrode, whereby the amplification of said amplifier is regulated automatically.

2. In a carrier-current signaling system, in combination, a vacuum tube amplifier having a cathode and a control electrode, a vacuum tube detector coupled directly to the output of said amplifier, said detector having a cathode and an output electrode, means for maintaining said detector cathode at substantially the same potential as said amplifier cathode, means for maintaining said output electrode at a negative potential with respect to said cathodes, means causing said output electrode to become more negative in the presence of an amplified signal, and a direct-current connection between said output electrode and said control electrode.

3. A combination according to claim 2 in which the means for maintaining the detector output electrode at a negative potential with respect to said cathodes is a resistance connected between said output electrode and the detector cathode.

4. In a modulated carrier-current signalling system employing a carrier-current amplifier and rectifier, which rectifier produces a modulated uni-directional voltage; a direct-current connection from said rectifier to an element of said amplifier whereby the amplification is regulated automatically, and a connection from said rectifier to a modulation current amplifier whereby the signal is further amplified, said connection from said rectifier to said modulation current amplifier including a condenser in series for preventing the uni-directional component from being impressed upon the input of said modulation current amplifier.

5. In a signaling system, a vacuum tube amplifier having a cathode and a control electrode, a detector coupled to said amplifier, said detector having an output electrode, means for maintaining said output electrode normally negative relative to at least part of said amplifier cathode, means for causing said output electrode to become more negative in the presence of an amplified signal, and a direct-current connection between said control electrode and said output electrode, whereby the amplification of said amplifier is regulated automatically.

6. In a signaling system a vacuum tube amplifier having a cathode and a control electrode, a second vacuum tube having an output electrode, means for coupling the output of said amplifier with said second tube, means for maintaining said output electrode normally slightly negative relative to at least part of said cathode, means for causing said output electrode to become more negative in the presence of an amplified signal, and a direct current connection between said control electrode and said output electrode, whereby the amplification of said amplifier is regulated automatically.

7. In a signaling system, a vacuum tube amplifier having an anode, a cathode and a control electrode, a detector coupled to said amplifier, said detector having an output electrode, means for maintaining said output electrode normally negative relative to at least part of said amplifier cathode, means for causing the said output electrode to become more negative in the presence of an amplified signal, a tuning arrangement for tuning said amplifier to a desired signal, a direct current connection between said control electrode and said output electrode, whereby the amplification of said amplifier is regulated automatically, and means for visually indicating the condition of resonance in said tuning arrangement, whereby tuning is facilitated.

8. An arrangement according to claim 7 in which ~~said tuning arrangement and~~ said means for visually indicating the condition of resonance are connected in the an[illegible] cuit of said amplifier.

~~9. In a signaling system, a vacuum tube~~ amplifier having a cathode and a control electrode, a vacuum tube detector coupled to the output of said amplifier, said detector having a cathode and an output electrode, means for maintaining said detector cathode at a potential greatly negative relative to said amplifier cathode, means for maintaining said output electrode at a potential normally slightly negative relative to said amplifier cathode, means for causing said output electrode to become more negative in the presence of an amplified signal and a direct current connection between said output electrode and said control electrode whereby the amplification of said amplifier is regulated ~~automatically.~~

9. ~~10.~~ In a signaling system, a vacuum tube amplifier having a cathode and a control electrode, a diode detector coupled to said amplifier, said detector having an anode, means for maintaining said anode normally negative relative to at least part of said amplifier cathode, means for causing said anode to become more negative in the presence of an amplified signal and a direct current connection between said control electrode and said anode, whereby the amplification of said amplifier is regulated automatically.

10. ~~11.~~ In a signaling system, a vacuum tube amplifier having a cathode and a control electrode, a diode detector coupled to said amplifier, said detector having a cathode and an anode, means for maintaining said cathodes at substantially the same potential, means including a high resistance connected

Ex[illegible] A

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between the detector anode and cathode for maintaining said anode normally slightly negative relative to said cathodes, means for causing said anode to become more negative in the presence of an amplified signal, and a direct-current connection between said control electrode and said anode, whereby the amplification of said amplifier is regulated automatically.

12. In a signaling system a vacuum tube amplifier having a cathode and a control electrode, a second vacuum tube having an output electrode, means for coupling said amplifier with said second tube, means for maintaining said output electrode normally slightly negative relative to at least part of said cathode, means for causing said output electrode to become more negative in the presence of an amplified signal, a tuning arrangement for tuning said amplifier to a desired signal, and a direct current connection between said control electrode and said output electrode, whereby the amplification of said amplifier is regulated automatically, and means for visually indicating the condition of resonance in said tuning arrangement whereby tuning is facilitated.

In testimony whereof I affix my signature.

HAROLD A. WHEELER.

IN TESTIMONY WHEREOF, I affix my signature.

Harold A. Wheeler

OATH

STATE OF NEW YORK)
) SS:
COUNTY OF NEW YORK)

HAROLD A. WHEELER, the above-named petitioner, being duly sworn, deposes and says:

That he does verily believe himself to be the original, first and sole inventor of the improvement set forth and claimed in the foregoing specification, for which improvement he solicits [illegible]; that [illegible] he does not believe that the [illegible] before known or used; that he is a citizen of the United States of America, and [illegible] Great Neck, Long Island, [illegible] State of New York; that [illegible] Letters Patent belonging [illegible] specification, and hereby [illegible] are wholly inoperative [illegible] specification, and [illegible] drawings, [illegible] description [illegible] 1, [illegible] 7, [illegible] United States Letters [illegible] ,784, [illegible] 5, [illegible]

his original patent No. 1,879,863 to which the petition herein relates, was directed to a modification adapted to be substituted in the drawings identified as Fig. 4, and that the insufficiency consists particularly in the absence of claims in the express language of claims 12 to 17 inclusive submitted herewith, and that the defect or insufficiency which renders such patent partly inoperative arose from inadvertence or mistake and without any fraudulent or deceptive intention on his part, that Exhibit A (pp. 1-20 inclusive) hereto attached and to be considered as a part hereof, contains by reference to a printed copy of the original patent, a true specification of the errors which it is claimed constitute such inadvertence or mistake, and that in Fig. 3 the two defects hereby corrected comprise the omission of a condenser and of a connection of the arrow 73 to the end of the adjacent resistance, neither of these defects having been present in the corresponding Fig. 3 of his parent application Ser. No. 203,879, filed July 7, 1927 (now pending), of which said original patent is a division.

[illegible]

Sworn to and subscribed before me this [illegible]th day of September, 1934.

Notary Public

745651

IN THE [illegible]

In the matter [illegible]
application [illegible]
United States Letters [illegible]
[illegible]
[illegible]
Harold [illegible]
assignor [illegible]
a corporation [illegible].

STATE OF [illegible]
COUNTY OF [illegible]

[illegible]

and says:

[illegible]

[illegible]

Patent No. 1,[illegible]

application [illegible]

"Volume Control";

That [illegible]

with whose assignee [illegible]

is made, in [illegible]

[illegible]

Patent No. [illegible]

[illegible] v. [illegible]

States District Court, [illegible]

this action [illegible]

is before the Court [illegible]

accessible at the [illegible]

application [illegible] accompanied [illegible] original patent grant.

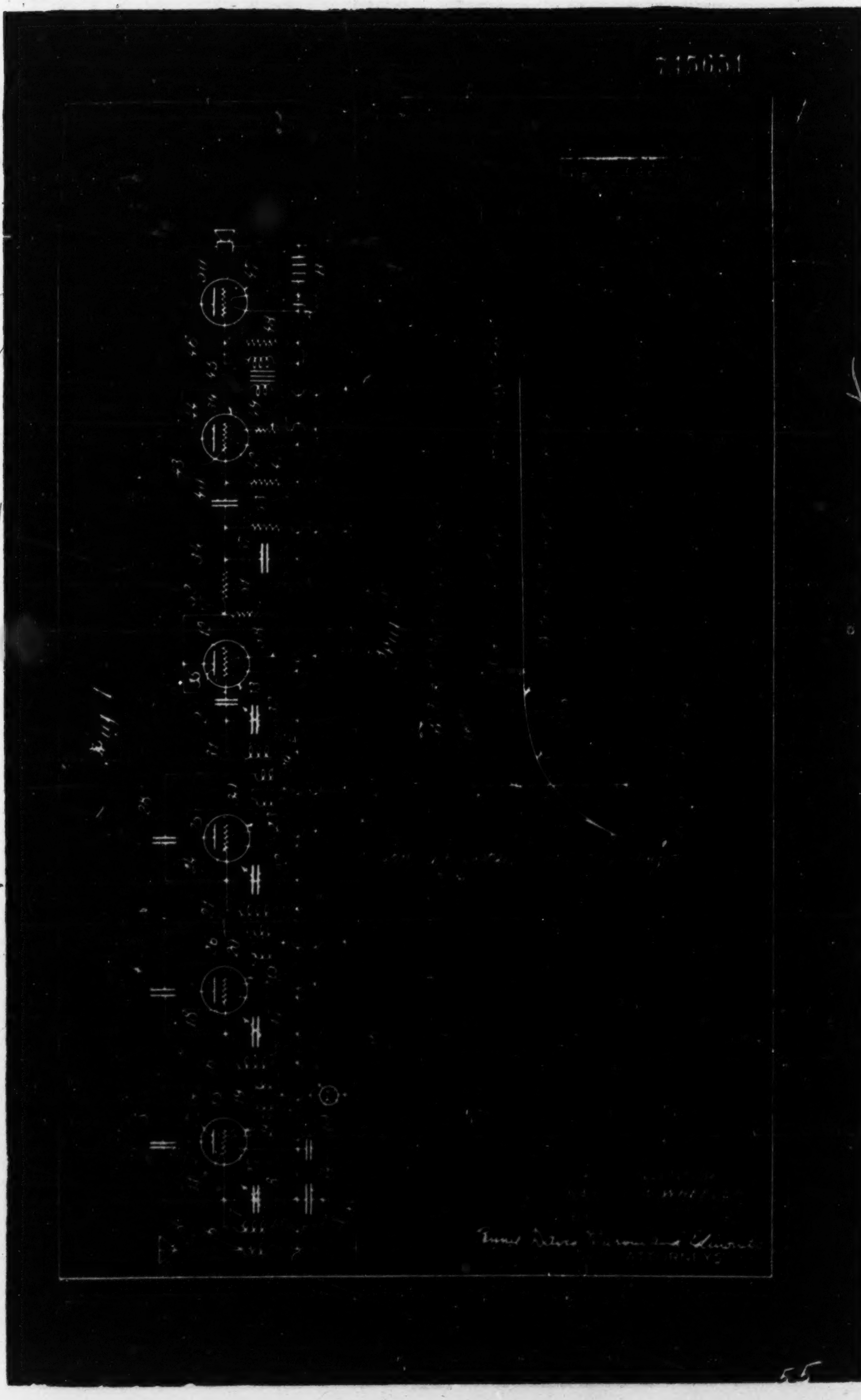
[illegible] of the Rules [illegible] patent [illegible], with [illegible] patent grant will [illegible] before the accompanying [illegible]

John A [illegible]

[illegible] before me this

day of September, 19[illegible].

[illegible]




745651

Div. 51 Room 5628 Paper No. 3

Address only "The Commissioner of Patents, Washington, D. C." and not any official by name

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON

All communications respecting this application should give the serial number, date of filing and name of the applicant

HSM:MCG December 13, 1934.

Please find below a communication from the EXAMINER in charge of this application.

Commissioner of Patents.

Applicant: H. A. Wheeler
Ser. No. 745,651
Filed Sept. 26, 1934
For Volume Control

Pennie, Davis, Marvin & Edmonds,
165 Broadway,
New York, N. Y.

DEC 13

This reissue application has been examined.

The following patents are cited as illustrating the condition of the art, and may be found useful in further consideration of the case:

Affel	1,574,782	Mar. 2, 1926	[illegible]
Heising	1,687,248	Oct. 9, 1928	179-44-12ux
Schelleng	1,8[illegible]	Dec. 1[illegible], 1931	179-44-1[illegible]
Bjornson	1,866,5[illegible]	[illegible]	17[illegible]-44-1[illegible]

The affidavit as to inaccessibility of the original patent is considered sufficient compliance with Rule 91 but before case [illegible]

The claims at present [illegible] unless, however, [illegible] the [illegible] case of [illegible] Davega City [illegible] [illegible]

plate and cathode of the rectifier RT should be reversed from the connections which are shown in the drawing, Fig. 1, since his entire description refers to a positive potential on the grid.

Heising does not appear to control volume but rather varies the bias of the amplifier tube in accordance with the modulation current to maintain the bias at an efficient point for amplification.

J. H. T.

Examiner

C3871-Re.

FEB 12 35

FEB 13 1935

IN THE UNITED STATES PATENT OFFICE

In re application of)
H. A. WHEELER)
Ser. No. 745,651) For: "Volume Control"
Filed Sept. 26, 1934)
Division 51, Room 5628)

Honorable Commissioner of Patents,

Washington, D. C.

S i r:

Kindly amend the drawings in the above-identified application as requested in a separate letter addressed to the Official Draftsman concerning the correction of a draftsman's error in Fig. 1.

R E M A R K S

This amendment is not intended to be specifically in response to official action of Dec. [illegible]. From that action, applicant understands that all of the claims are considered allowable but that no notice of allowance will be issued until the original [illegible] of Wheeler patent 1,87[illegible],862 has been submitted for cancellation. This matter will be taken care of in due course.

Respectfully submitted,

[illegible]

Attorneys for the Applicant.

Dated: New York, N. Y.,

February 11, 1935.

C-871-RL. 23577

FEB 13 1935

IN THE UNITED STATES PATENT OFFICE

In re application of)
H. A. WHEELER)
Ser. No. 74[illegible],651) For: "Volume Control"
Filed Sept. 2[illegible], 1934)
Division 51, Room 5628)

ATTENTION OF THE OFFICIAL DRAFTSMAN

Honorable Commissioner of Patents,

Washington, D. C.

S i r:

Kindly amend Fig. 1 of the drawings in the above-identified application as follows:

Referring to the "B" battery at the extreme right of Fig. 1, the battery now is represented by three long light vertical lines and four short heavy vertical lines. Since each pair of lines represents one battery cell, there should be a like number of each of the short and long lines. Consequently, it is requested that the short heavy line below the + sign be erased, and the connection at that end of the battery be continued to the left to meet the long light line representing the positive terminal of the battery.

Kindly charge the cost of this correction to the account of the undersigned.

Respectfully submitted,

Attorneys for the Applicant.

Dated: New York, N. Y., February 11, 1935.

CORRECTED

ACCOUNT

5351T

d

C-3871Re

IN THE UNITED STATES PATENT OFFICE

In re Application of:)
Harold A. Wheeler,)
Serial No. 745,651)
Filed: Sept. 28, 1934)
Reissue of Pat. No. 1,879,863)
Div. 51 Room 5628)

For: "VOLUME CONTROL".

PATENT OFFICE MAY 2

A M E N D M E N T

Honorable Commissioner of Patents,
Washington, D. C.

S i r:

In response to the Office Action of December 13, 1934, please amend the above-identified application as follows:

Page 2, line 4, after "periodically" insert a comma.

Page 5, lines 29 and 30, cancel "Through this filter" and substitute -- As appears from the constants hereinafter given, the characteristics of this filter are such that it passes --;

line 30, cancel "is transferred".

Page 7, line 5, for "present in the" substitute -- applied from --;

same line, after "36" insert -- to the grid 11 --.

Ser. No. 745,651. H. A. Wheeler. "Volume Control".

Page 8, lines 23 and 24, enclose in a parenthesis "or space current";

line 27, for "increasing" substitute -- increase of --.

Page 9, lines 10 to 12 cancel "degree of . . . listener is then" and substitute, -- level at which the volume is maintained uniformly is --.

Page 12, line 16, after the numeral "32" insert a comma.

Page 13, line 12, include in a parenthesis the words "instead of one".

Page 15, lines 9 and 10, cancel "a three-[illegible] . . . . vacuum tube, and" and substitute, -- if a three-electrode detector were used in an automatic amplification control system, --;

line 11, cancel "then";

line 12, substitute, -- therefore, if -- for "If"; same line after "were" insert -- so --;

lines 15 and 16, cancel "in an automatic amplification control system".

Page 16, lines 4 and 5, cancel "may be employed with equal effectiveness to any" and substitute therefor, -- is generally applicable to --.

Ser. No. 745,651. H. A. Wheeler. "Volume Control".

REMARKS

The amendments herein requested to be made to the specification are for the purpose of clarifying and making more accurate the description of the circuit connections illustrated in the drawings, and of the inherent operation of the system.

Accompanying this amendment is a letter addressed to the Commissioner of Patents surrendering the original deed, in the name of Harold A. Wheeler, for U. S. Letters Patent No. 1,879,863, in accordance with the affidavit of John R. Binns, executed September 24, 1934 and filed with the application for reissue above identified.

Since all of the claims have been allowed, this reissue application is now in condition for immediate allowance, which action is respectfully requested.

Respectfully submitted,

Attorneys for Applicant.

New York, N. Y.
May 1 , 1935.

401

TITLE REPORT

No.

Name.

The title appears [illegible] to be vested in

Examined up to and including

Title certificate issued

No further [illegible] including

53[illegible]C

-3871Re

PATENT OFFICE [illegible]
MAY 2
[illegible]

IN THE UNITED STATES PATENT OFFICE

In re Application of:
Harold A. [illegible],
Serial No. [illegible],
Filed [illegible], 1934 For: "VOLUME CONTROL".
[illegible]
[illegible]

[illegible]

[illegible]

[illegible]

May [illegible], 193[illegible].

1559863

THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

Whereas

Commissioner of Patents

Whereas

Now therefore these Letters Patent

for the term of SEVENTEEN years

745651

Sept. 27, 1932. H. A. WHEELER 1,879,863

VOLUME CONTROL

Original Filed July 7, 1927 4 Sheets-Sheet 1

Fig. 1.

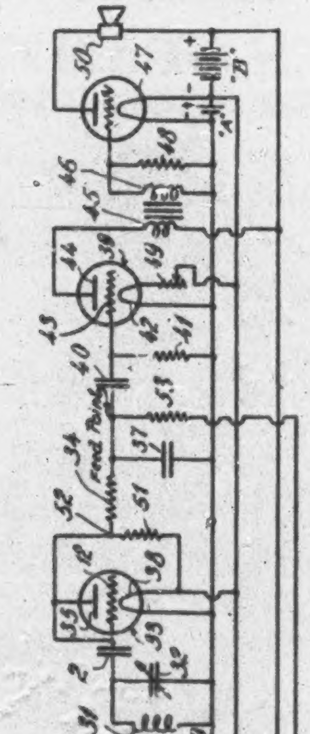
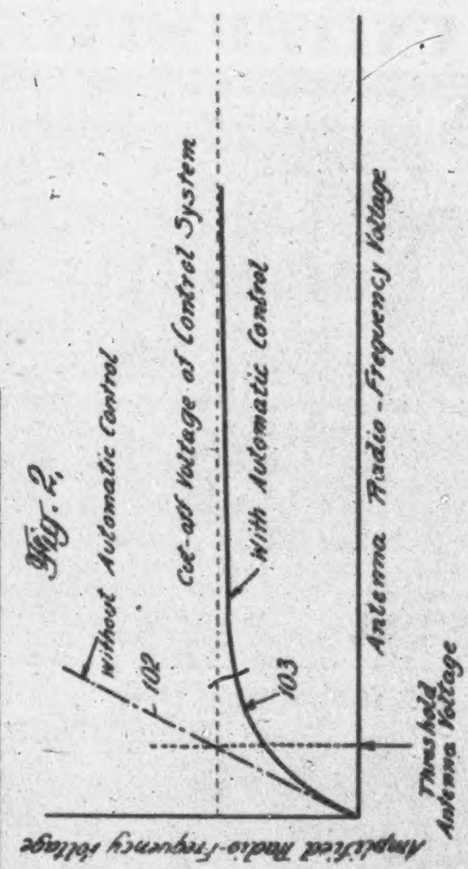


Fig. 2.

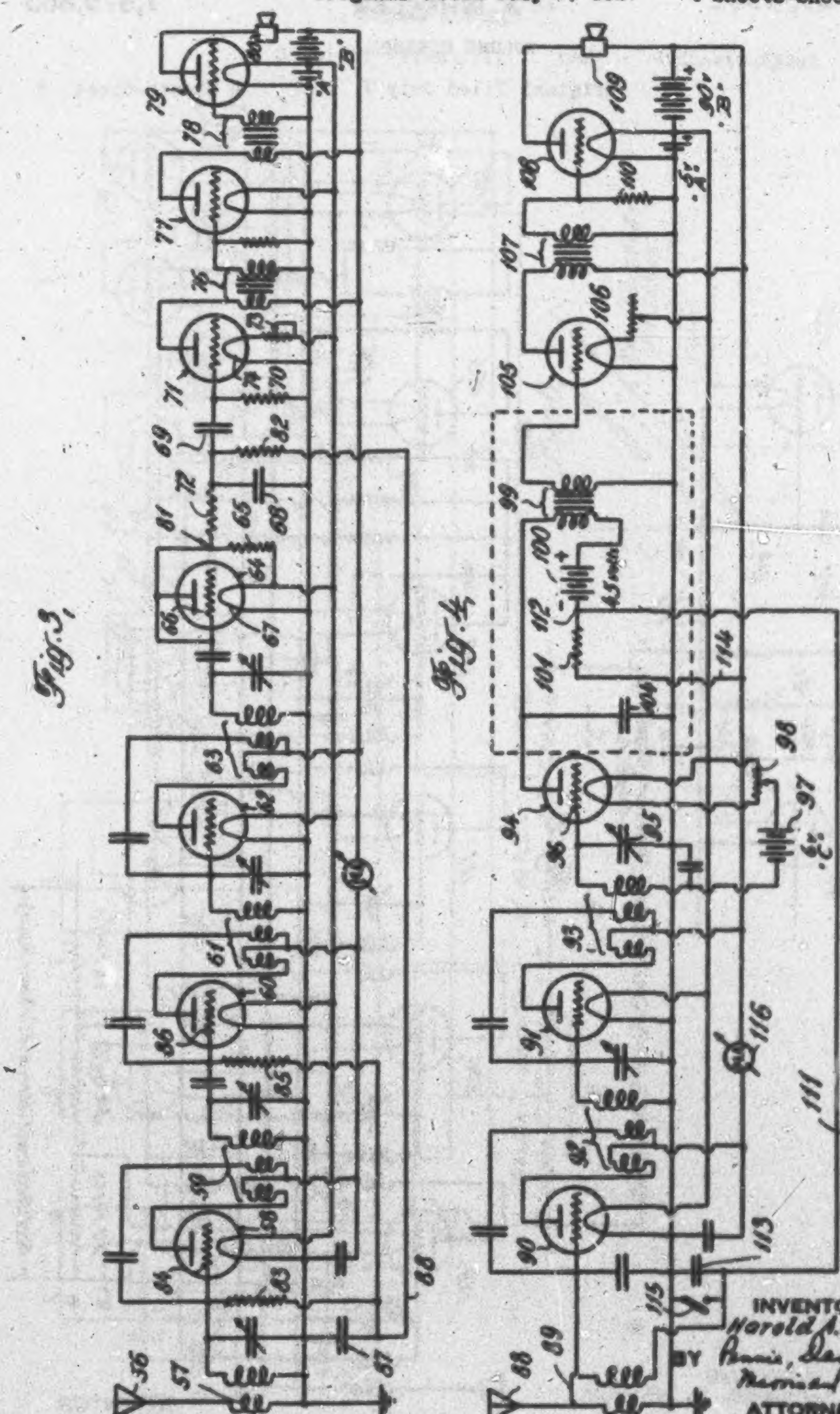


INVENTOR
Harold A. Wheeler
BY
Pennie, Davis, Marvin and Edmonds
ATTORNEYS

Sept. 27, 1932. H. A. WHEELER 1,879,863

VOLUME CONTROL

Original Filed July 7, 1927 4 Sheets-Sheet 2

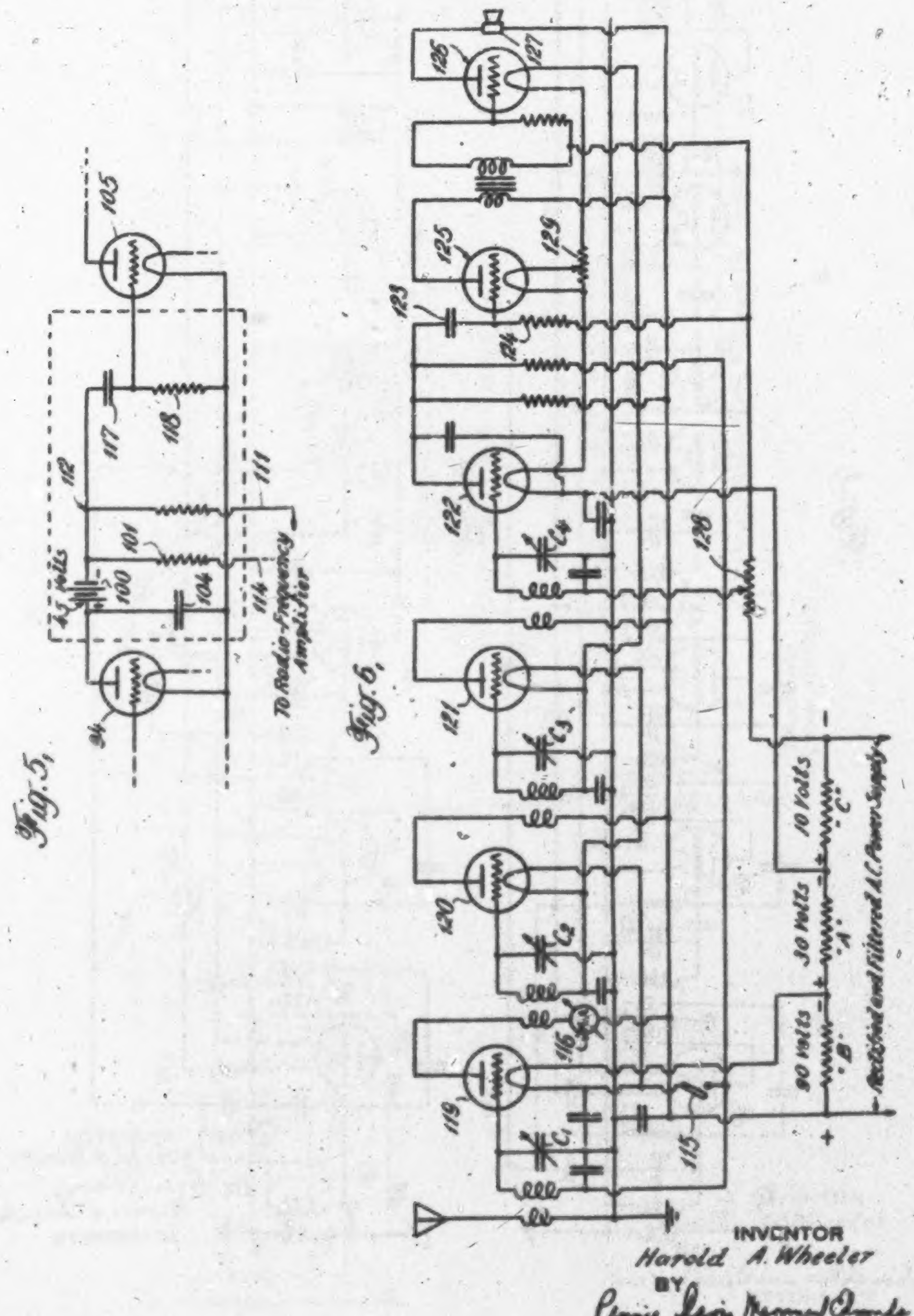


INVENTOR
Harold A. Wheeler
BY Pennie, Davis, Marvin and Edmonds
ATTORNEYS

Sept. 27, 1932. H. A. WHEELER 1,879,863

VOLUME CONTROL

Original Filed July 7, 1927 4 Sheets-Sheet 3



INVENTOR
Harold A. Wheeler
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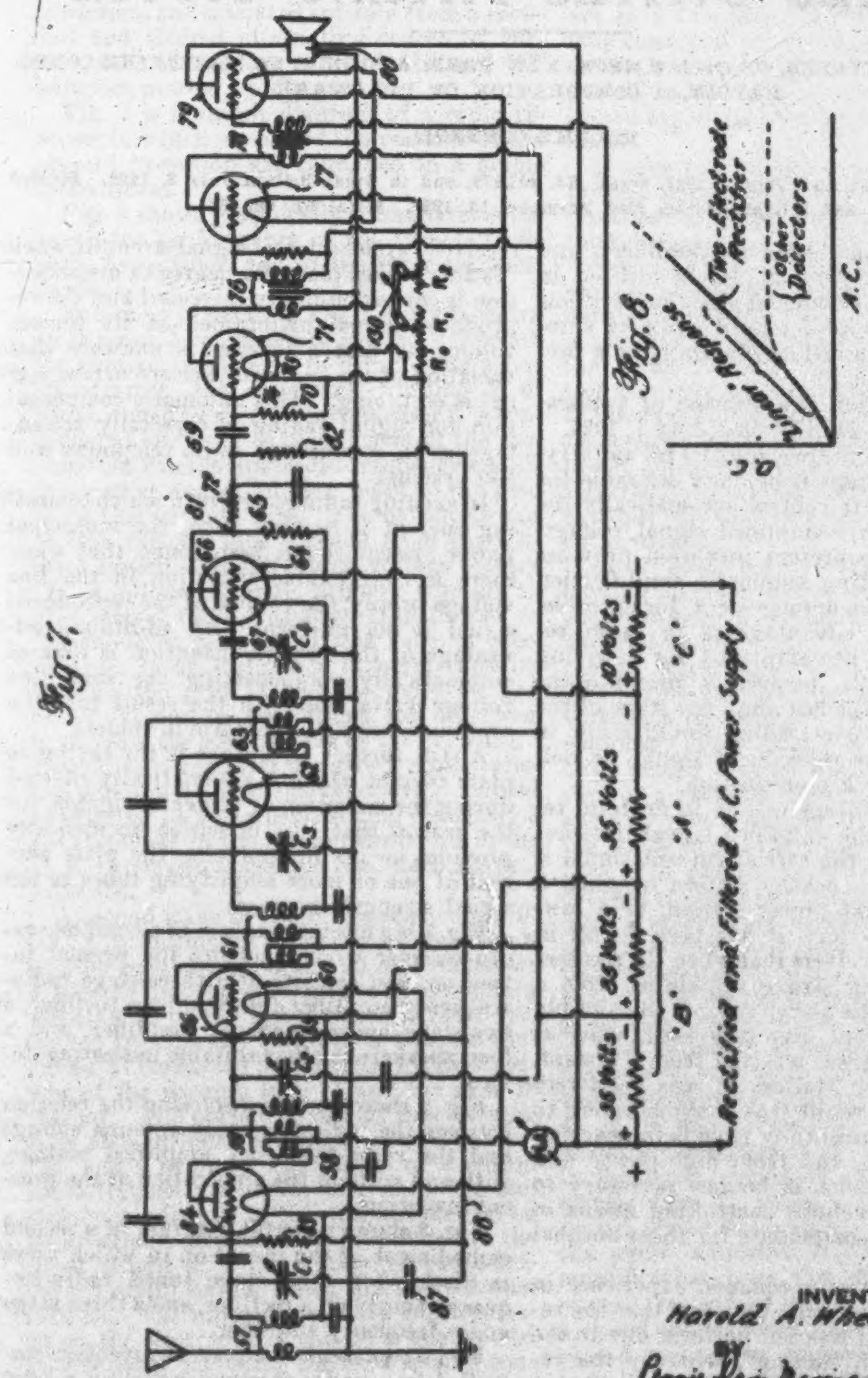
Pennie, Davis, Marvin & Edmonds
ATTORNEYS

Sept. 27, 1932. H. A. WHEELER 1,879,863

VOLUME CONTROL

Original Filed July 7, 1927 4 Sheets-Sheet 4

Fig. 7, Fig. 8,



INVENTOR
Harold A. Wheeler
BY
Pennie, Davis, Marvin and Edmonds
ATTORNEYS

Patented Sept. 27, 1932 1,879,863

UNITED STATES PATENT OFFICE

HAROLD A. WHEELER, OF GREAT NECK, NEW YORK, ASSIGNOR TO HAZELTINE CORPORATION, A CORPORATION OF DELAWARE

VOLUME CONTROL

Original application filed July 7, 1927, Serial No. 203,879, and in Great Britain July 3, 1926. Divided and this application filed November 13, 1930. Serial No. 495,386.

This invention relates to amplifiers, and more particularly to amplifiers utilized in modulated carrier-current signaling systems wherein the limit of amplification is automatically maintained substantially at a predetermined level.

This application is a division of application Serial No. 203,879, filed July 7, 1927.

When amplifiers are employed for amplifying a signal voltage it becomes desirable for various reasons to control automatically the amplitude of this amplified signal voltage. To this end the present invention provides means for effecting automatic amplification control. Such an arrangement, for example, is particularly advantageous in radio receivers such as are employed for receiving broadcast signals, because it prevents the overloading of the last amplifier stage of the receiver, which overloading would result in distortion of the reproduced signal, as well as loud and harsh reproduction.

Another advantage resides in uniform reproduction of the amplified signal irrespective of whether the carrier-current signal is received from a nearby station or from a distant or a high-power station, or a low-power station, since it has been found in former radio receivers that when the receiver was reproducing strong signals as from a nearby, or a high-power station, the audibly reproduced signal was very loud, whereas when the signal was received from a distant, or a low-power station, it was relatively weak, with the result that if signals were to be reproduced uniformly from both near and distant stations, and from high-power and low-power stations, it became necessary to readjust some volume controlling means in the receiver to compensate for these unequal signals.

It has also been a common experience in the use of former radio receivers that the reproduced signal was not uniform due to the phenomenon of "fading", whereby the received signal occasionally, or periodically became much weaker, or faded almost to the point of inaudibility. Since the present invention provides an amplifier which automatically compensates for inequalities in the received carrier-current signal strength, when "fading" takes place the degree of amplification is correspondingly increased and the reproduced signal maintained at its former volume, so that a listener is unaware that variation of the received carrier-current signal is occurring. This automatic compensation for signal fading is especially advantageous in commercial radio telephony and like systems.

In existing radio receivers in which operating current is derived from the municipal power system, it has been found that when there is considerable variation in the line voltage supply, the volume of the reproduced signal is not uniform. An additional advantage of the present invention is that of automatically compensating for such line voltage variations with the result that the reproduced signal is uniform in volume.

A still further advantage is the saving in plate current which is automatically effected during the reception of powerful signals, for the reason that this invention incidentally provides means for reducing the plate current of one or more amplifying tubes as the signal strength increases.

Fig. 1 is a circuit diagram of a complete radio receiver which includes the present invention, and consists of a three-stage radio-frequency amplifier followed by a rectifier, a two-stage audio-frequency amplifier, and a loud speaker, or other suitable indicating device.

Fig. 2 shows curves disclosing the relation between the radio-frequency antenna voltage and the radio-frequency amplified voltage, with and without the application of the present invention.

Fig. 3 shows a circuit diagram of a second embodiment of the invention in which there is disclosed a three-stage tuned radio-frequency amplifier, a rectifier, and a three-stage audio-frequency amplifier.

Fig. 4 represents the present invention embodied in a radio receiver including a two-stage radio-frequency amplifier, a detector, and a two-stage audio-frequency amplifier.

Fig. 5 shows a modified form of coupling arrangement and controlling network which

may be substituted for the corresponding elements inclosed in the dotted rectangle of Fig. 4.

Fig. 6 shows a diagrammatic arrangement of a radio receiver incorporating the present invention, and operated entirely from a rectified and filtered alternating source of current, thus eliminating the "A", "B" and "C" batteries now so widely used.

Fig. 7 is a circuit diagram of a radio receiver in which several of the features of the present invention are combined in a single embodiment.

Fig. 8 shows graphically a comparison between the performance of the two-electrode valve or rectifier, and of the three-electrode detector.

Referring in detail to Fig. 1, there is shown an antenna 5 connected to ground 1 through the primary winding 6 of a radio-frequency transformer, the secondary winding 7 of which, tuned by a variable condenser 8, is connected at one point to the filament of the vacuum tube 9 in the first radio-frequency amplifying stage and at another point to the grid 11 of this vacuum tube. The output circuit of this vacuum tube extends from the filament system, through a high-voltage battery "B", a milliammeter 10, primary winding 13 of a second radio-frequency transformer to the anode or plate 14 of this vacuum tube. In order to neutralize the inherent capacity between the grid 11 and the plate 14, and thereby to prevent oscillations, and otherwise to increase the effectiveness of the present invention as hereinafter described, a neutralizing winding 19, electromagnetically coupled to winding 13, and a neutralizing condenser 3 are employed in the manner described in the U. S. patents to Hazeltine Nos. 1,489,228 and 1,533,858.

A second stage of radio-frequency amplification including the vacuum tube 15 neutralized by cooperation of coil 26 and condenser 4, like the first stage, comprises the secondary winding 16 of the last-mentioned radio-frequency transformer tuned by a variable condenser 17 connected between the filament system of the vacuum tube 15 and the grid 18 thereof. The output circuit of this vacuum tube also includes the high-voltage battery "B" and a primary winding 20 of a second radio-frequency transformer, while the secondary winding 21 of this transformer tuned by a variable condenser 22 is included in the input circuit of a third stage of radio-frequency amplification which includes vacuum tube 23. The inherent capacity effective between the electrodes 24 and 25 is neutralized by a network including the neutralizing condenser 28 and the neutralizing winding 29 as described in the mentioned patents. The output circuit of the vacuum tube 23 includes the primary winding 30 of a third radio-frequency transformer and the high-voltage battery "B". The secondary winding 31 of this last-mentioned transformer, tuned by a variable condenser 32, is connected in the input circuit of a rectifier 33 which input circuit includes the fixed condenser 2, the rectifier employed may be of the type commonly known in the art as a two-electrode "Fleming" valve, or may consist of an equivalent such as a three-electrode vacuum tube, as shown, having its grid 12 and its plate or anode 35 directly connected together to comprise in effect a single anode.

It may here be noted that throughout the present specification and claims the terms "rectifier" and "detector" are, in general, used interchangeably, the terms "rectifying" and "converting" being employed in the general sense to include the process of changing alternating current into a form of direct current or modulated unidirectional current. Likewise, the terms "carrier-current" and "modulation current" may be substituted, respectively, for "radio-frequency current" and "audio-frequency current", since the description herein of radio-frequency amplifiers and audio-frequency amplifiers is merely by way of example of a typical embodiment of the present invention.

In the absence of the present invention including the control circuit 36, to be described, the three-stage amplifier functions in a manner well-known in the art to amplify the incoming signal intercepted on the antenna 5. The output circuit of the rectifier 33 includes what may be termed a "rejector" circuit for stopping radio-frequency currents which have passed through the rectifier, and consists of a network including a resistance 34 and a by-pass condenser 37 connected between the anode 35 and the filament 38 of the rectifier. The output circuit of the rectifier is coupled to the input circuit of an audio-frequency amplifying vacuum tube 39 through an audio-frequency-pass filter including a fixed condenser 40 and an impedance 41 connected between the filament 42 and the grid 43 of this vacuum tube. The output circuit of this amplifier is connected between the filament 42 and plate 44 through the high-voltage battery "B" and the primary winding 45 of an audio-frequency transformer, the secondary winding 46 of which is connected in the input circuit of a second audio-frequency tube 47, while a resistance 48 connected across the winding 46 serves to give the audio amplifier substantially uniform amplification over the desired frequency range. Instead of employing resistance 48, a closed copper band of suitable size may be placed around the transformer winding so as to be electromagnetically coupled thereto. A loud speaker or other reproducing device 50, or if required, a coupling device for a telephone system, is connected in the output circuit of the last audio-frequency amplifying tube 47. It is presumed that adequate pre-

cautions against undesired electromagnetic coupling between the various radio-frequency coupling transformers are included in all of the arrangements herein disclosed.

In accordance with the main feature of the present invention, means are provided to control automatically the degree of amplification effected in the radio-frequency amplifying stages. These means include a resistance 51, connected between the filament 38 and the anode 35 of the rectifier, through which the pulsating rectified or converted current flows, thereby developing a negative voltage at terminal 52. This negative voltage is applied over conductor 36 through the impedance 53 and the secondary winding 7 of the first radio-frequency transformer to grid 11 of the first radio-frequency stage. Impedance 53, together with blocking condenser 54, is effective to filter out and reject any audio-frequency currents which otherwise might be present in the conductor 36.

To complete the description of the system illustrated in Fig. 1 certain design data or constants are given herewith. It should be understood, however, that these, as well as all other constants appearing in the present specification, are mentioned merely by way of example in describing certain specific embodiments which in practice have proved eminently satisfactory, and are not intended to suggest any specific limitations as to the scope of this invention. Accordingly, fixed condenser 2 may be of 0.0005 microfarads; 37 of 0.0001 microfarads; 54 of 0.01 microfarads; 40 of 0.005 microfarads; resistance 51 of 1 megohm; 34 of 1 megohm; and 41 and 53 of 2 megohms each.

In the operation of the receiver shown in Fig. 1 a signal intercepted on the antenna 5 is successively amplified through the neutralized radio-frequency stages indicated by the vacuum tubes 9, 15 and 23. This amplified signal voltage is then rectified by the rectifier 33, and the rectified pulsating current is successively amplified by the audio amplifying stages including vacuum tubes 39 and 47, after which it may be reproduced as sound by the loud speaker 50. When the rectified or converted signal current flowing through the resistance 51 is greater than a predetermined value, there is developed at the terminal 52 sufficient negative biasing voltage which in turn is impressed, through the conductor 36, upon the grid 11 of the vacuum tube 9, to reduce the amplification of this tube. It will be apparent that as the magnitude of the rectified current flowing through resistance 51 decreases with weaker signals, the voltage at terminal 52 becomes less negative, and the negative biasing voltage impressed upon the grid 11 also diminishes so that the vacuum tube 9 effects an increased degree of amplification. In this manner, the radio-frequency voltage applied to the input of the rectifier is maintained at a nearly constant predetermined value, and the volume of the reproduced signal is substantially uniform under all conditions. The degree of volume of the reproduced signal is then determined by adjustment of rheostat 49 which controls the heating current in the filament 42 of the first audio-frequency amplifying tube 39. The neutralization of the grid-plate capacity of the radio-frequency amplifying tubes is, in combination with the present invention, particularly valuable in that it allows an increase in the effectiveness of the amplification control, because such neutralization prevents radio-frequency energy from passing through the grid-plate capacity of the tubes. Thus the relay action of the tubes is almost entirely subject to the control by grid bias voltage provided in accordance with this invention.

The time required for operation of the control system would ordinarily be determined by the lowest audio-frequency modulation which must be reproduced. Fading, for example, might be considered a form of modulation; the frequency of the rise and fall of signals due to fading being the frequency of modulation. If this frequency of modulation be increased sufficiently, the effect will be audio-frequency modulation. It will thus be seen that if the automatic control attained by the present invention be allowed to respond too quickly, it will tend to smooth out the desired modulation of the signals at the lower audio frequencies. Hence, a time constant of operation is chosen which will be greater than the period of the audio frequencies which the system is intended to amplify. This time constant of the control circuit is equal to the product of the series resistance and the shunt capacitance of the grid bias circuit, represented in Fig. 1 by resistance 53 and capacitance 54. However, since the time constant can always be reduced to a value equal to the period of the lowest modulation frequency, it may readily be set to meet the requirements of nearly any special case which may arise. For example, a value of two million ohms resistance and of 0.1 microfarad capacitance gives a time constant of one-fifth of a second, which does not appreciably affect the modulation of frequencies above five cycles. While this constant is greater than required from the point of view of satisfactory audio-frequency quality in the reproduction of music, there appears to be no need for more rapid control under the conditions usually encountered. The use in this connection of condensers of large capacitance, such as one-tenth microfarad, likewise introduces another convenience in that the condensers may also serve to by-pass radio frequencies in order to prevent undesired coupling between the detector circuit and the first radio-frequency amplifying tube because of some impedances

common to those two portions of the apparatus.

For a better understanding of the present invention reference is made to Fig. 2 from which it will be appreciated that in a system similar to that illustrated in Fig. 1, but in which no means for automatically limiting the degree of amplification is included, the amplified radio-frequency voltage is proportional to the radio-frequency antenna voltage, as indicated by curve 102. When, however, the present invention is employed in such an amplifier, the relation between the radio-frequency antenna voltage and the amplified radio-frequency voltage is indicated by curve 103 from which it will be seen that when at least a certain predetermined radio-frequency antenna voltage is present, (herein referred to as the "threshold antenna voltage") the amplified radio-frequency voltage approaches—but is always less than—another certain predetermined voltage value (herein referred to as the "cut-off voltage").

The modification illustrated in Fig. 3 is an especially desirable form of the present invention, and includes antenna 56, connected by means of a transformer 57 to a neutralized three stage tuned radio-frequency cascade amplifier including the vacuum tubes 58, 60 and 62 coupled by transformers 59 and 61. The last stage of the amplifier is connected by a transformer 63 to a two-electrode rectifier 64 of the type already described, the output circuit of which, including the resistance 65, is connected between the anode 66 and filament 67 of the rectifier, as previously explained. Resistance 72 and condenser 68 associated with this output circuit, constitute a "rejector" network which filters out the radio-frequency current component in the output circuit of the rectifier 64, while the network including condenser 69 and resistance 70 constitutes an audio-frequency-pass filter for coupling the output circuit of the rectifier to the input circuit of the audio-frequency amplifier which includes vacuum tube 71. Rheostat 73 controls the heating current supplied to the filament 74 of this vacuum tube, and thereby permits a manual adjustment of the volume of the reproduced signal desired by the listener. Audio-frequency transformer 76, which is preferably of a low ratio of transformation, couples the output circuit of vacuum tube 71 to a second audio-frequency amplifying tube 77. This last vacuum tube in turn is coupled by a second audio-frequency transformer 78 to a third audio-frequency amplifying tube 79 in the output circuit of which there is included a loud speaker 80.

In this arrangement automatic amplification control is effected in a manner slightly different from that shown in the diagram of Fig. 1, since in this instance the radio-frequency voltage of the signals intercepted by the antenna 56 is successively amplified by three neutralized tuned radio-frequency amplifying stages including the vacuum tubes 58, 60 and 62, of which two are controlled in accordance with the present invention. The amplified radio-frequency current is rectified by the rectifying valve 64, and successively amplified at audio-frequency by the vacuum tubes 71, 77 and 79. The rectified current in the output circuit of the rectifier flows through the resistance 65, and thereby develops a negative voltage at the terminal 81, which voltage is applied through the impedances 72, 82, 83 and 85 to the grids 84 and 86 of the radio-frequency amplifying tubes 58 and 60. By thus simultaneously controlling the degree of amplification of two successive radio-frequency amplifying stages a greatly increased uniformity of regulation is attained. Impedance 82 and the condenser 87 constitute an audio-frequency-stop filter, so that substantially only direct-voltage is impressed upon the grids 84 and 86. It will be understood that the voltage developed at terminal 81 is a function of the amplified radio-frequency voltage delivered to the input circuit of the rectifier by the radio-frequency amplifying tubes 58, 60 and 62, and therefore, as the negative voltage at terminal 81 tends to increase with the increased signal, the resulting increase of biasing voltage impressed upon the grids of the tubes 58 and 60 limits the degree of amplification effected in the radio-frequency stages including those tubes.

In this arrangement the constants for the various resistances and condensers may, for example, be the same as those for the corresponding elements in Fig. 1. In addition the grid resistances 83 and 85 may have a value of 2 megohms each; and the grid condensers connected at the junction of these resistances and the grid electrodes 84 and 86 may each be of 0.001 microfarad capacity.

The modification shown in Fig. 4 differs from the arrangement of Figs. 1 and 3 mainly in that it employs a three-electrode vacuum tube which functions in the manner of the well-known three-electrode detector, and also effects rectification, or conversion, of the radio-frequency carrier current to control amplification in the first radio-frequency stage of the receiver. As in the preceding arrangements, there is here employed an antenna or other suitable signal interceptor 88 coupled by means of a radio-frequency transformer 89 to a two-stage neutralized tuned radio-frequency amplifier including the vacuum tubes 90 and 91 coupled by means of a radio-frequency transformer 92. The output circuit of the last stage of the amplifier is connected by means of radio-frequency transformer 93 to the tuned input circuit of a three-electrode vacuum tube detector 94, which input circuit is tuned by the inductance of the secondary winding of trans-

former 93 in shunt to variable condenser 95. A suitable negative voltage is maintained on the grid 96 of the detector tube, through the secondary winding of transformer 93, by "C" battery 97 and by potentiometer 98 connected across the filament of the detector tube. By means of this potentiometer connection, a negative voltage may be applied to the grid 96 varying from one volt to a maximum of five volts; the minimum value being the difference between the six volts of "C" battery 97 and the voltage drop across the filament of the detector. The output circuit of the detector includes the primary winding of transformer 99, a 45-volt battery 100 and a 500,000 ohm resistor 101, connected in series between the anode of the detector and the common "B" battery. A fixed condenser 104 by-passes the radio-frequency current that has passed through the detector, while the audio-frequency component of the rectified, or converted, current is transferred through the audio-frequency transformer 99 to the input circuit of an audio-frequency amplifying vacuum tube 105, the filament circuit of which includes rheostat 106 for controlling the arbitrary volume level of the amplified signals. The output circuit of the audio-frequency amplifier 105 is coupled by means of an audio-frequency transformer 107 to the input circuit of a second audio-frequency amplifying tube 108. The output circuit of this vacuum tube includes the usual loud speaker or indicating device 109. A resistance 110 is connected across the secondary winding of transformer 107 to secure substantially constant amplification within the frequency range of the audio-frequency amplifier, especially when the plate resistance of the preceding tube 105 is high as a result of the adjustment of rheostat 106.

For controlling the amplitude of the radio-frequency voltage applied to the input circuit of detector 94, a conductor 111 is connected at point 112 common to a terminal of resistor 101 and battery 100, and thence through the secondary winding of transformer 89 to the grid of the first radio-frequency amplifying tube 90. A by-pass condenser 113 connecting the conductor 111 to the filament system serves to filter out and reject any audio-frequency currents present in the circuit including the conductor 111, thereby insuring that these currents have no effect on the grid of the vacuum tube 90. Battery 100 is the source of negative biasing voltage applied to the control grid, or control-electrode, of the radio-frequency amplifying tube, this battery being so connected to the output circuit of the detector, or rectifier, that fluctuations of voltage in the detector output circuit cause equal fluctuations in the negative biasing voltage impressed upon the control-grid.

In this embodiment, condensers 104 and 113 may be of 0.0005 microfarad and 1 microfarad capacity, respectively; while resistance 101 may have a value of 0.5 megohm.

In adjusting the receiver of Fig. 4, it is necessary to determine the correct setting of the detector grid potentiometer 98. This adjustment should be made while there is no signal being received, as follows: First, the switch 115 is closed, and the normal plate current of the tube 90 is noted on milliammeter 116. Then the switch is opened, thus placing the control circuit in operation. In general, the plate current of vacuum tube 90 will change when the switch is opened, since the grid voltage of this tube is dependent upon the control circuit. By varying the grid voltage of the detector by potentiometer 98, the plate current of tube 90 is then adjusted to the normal value; and the apparatus is ready for operation. Upon receipt of an amplified signal at the detector, the effect of the control circuit is to decrease the plate current through milliammeter 116, thereby reducing the amplification of the tube 90. When the receiver is tuned to the signal frequency, a minimum amplification is required, so that when the condition of resonance is attained, the plate current of tube 90 is at a minimum value.

It is believed unnecessary to explain the operation of the two radio-frequency amplification stages and of the detector, or of the two audio-frequency amplification stages, for in operation they are substantially similar to those of the now well-known type of radio receiver employing neutralized two-stage radio-frequency and two-stage audio-frequency amplifiers. The control circuit operates, in the arrangement of Fig. 4, substantially in the same manner as in Figs. 1 and 3, to apply a negative biasing voltage to the grid of the radio-frequency amplifying vacuum tube 90, this voltage being a function of the radio-frequency voltage which has been amplified by the vacuum tubes 90 and 91 and then applied to the input circuit of detector 94. Since the voltage applied over conductor 111 is a function of the amplified radio-frequency voltage, there is a maximum, or cut-off, detector voltage determined by the constants of the circuit, as shown in Fig. 2, beyond which the radio-frequency amplifier is prevented from effecting further amplification. This arrangement maintains the finally-amplified radio-frequency voltage at substantially constant value.

Fig. 5 shows an alternative system for coupling the detector to the first audio-frequency amplifying tube of Fig. 4. The coupling arrangement of Fig. 5 included within the dotted rectangle, when substituted for the corresponding portion enclosed within the rectangle of Fig. 4, provides a modified form of the invention. Corresponding elements of these two figures are identified by the same

reference characters, from which it will be seen that Fig. 5 differs from Fig. 4 in that the transformer coupling between the detector 94 and the first audio-frequency amplifying tube 105 has been replaced by an impedance coupling arrangement including the condenser 117 and the impedance 118.

While this modification does not utilize a transformer having a step-up ratio such as is included in the arrangement of the former figure, it, nevertheless, introduces the advantage of effecting a more nearly constant degree of amplification at audio frequencies. When the modification of Fig. 5 is substituted in the system of Fig. 4, as described, the values of elements 104 and 101 may be the same as mentioned above; the resistance connected in lead 111 may be of 2 megohms; 118 of 2 megohms; 117 of 0.005 microfarad; and 113 of 0.5 microfarad.

Referring to Fig. 6, there is shown a radio receiver of the unneutralized type in which the so-called "A", "B" and "C" batteries have been replaced by a source of rectified and filtered alternating current. In this embodiment of the invention there are provided three stages of tuned radio-frequency amplification in which the vacuum tubes of the successive stages are designated 119, 120 and 121, respectively. These several stages are transformer-coupled; and the last stage of the amplifier is coupled to a three-electrode vacuum tube detector 122, the grid bias voltage of which is controlled by potentiometer 128. In the output circuit of detector 122, there is provided a "rejector" circuit, similar to that previously described, for filtering out radio-frequency currents that have passed through the detector; and also an audio-frequency network, or impedance coupling, including condenser 123 and impedance 124, for passing the audio-frequency component of the rectified signal to the first audio-frequency amplifying vacuum tube 125. The filament of this tube is shunted by rheostat 129 which functions as a manual volume control. This last tube is transformer-coupled to a second stage of audio-frequency amplification, including the vacuum tube 126, in the output circuit of which there is provided a loud speaker, or other suitable indicating device, 127, which on occasion may be replaced by a coupling device in a telephone system. The filaments of these six vacuum tubes are connected in series across a suitable resistance in the rectified, filtered source of power supply, giving a potential difference of 30 volts, thus taking the place of an "A" battery. The necessary "C" or bias, voltage is derived from a potential difference across a resistance in that portion of the power supply indicated by the reference character "C", while the plate-current supply is similarly derived from a resistance in that portion of the power supply indicated by the reference letter, "B". It should be noted that the filament of the first radio-frequency amplifying tube 119 is connected to the positive terminal of the 30-volt "A" section of the power source, and that the filament of the detector tube 122 is connected to the negative terminal of this section. The constants of the elements of this embodiment may in general be similar to those suggested with reference to Fig. 5.

In adjusting the receiver of Fig. 6, the potentiometer 128 is adjusted with switch 115 open, as described in connection with the adjustment of the receiver of Fig. 4. This arrangement with the vacuum tube filaments connected in series obviates the necessity of a separate battery corresponding to 100 of Figs. 4 and 5, since the plate of the detector tube 122 can be positive relative to the filament of that tube, and at the same time maintains the grid of the first radio-frequency amplifying tube 119 negative relative to the filament of the same tube, due to the difference of potential between the two filaments. Thus the biasing voltage applied to the control-grid is derived from the voltage across the filaments instead of from a battery as in Figs. 4 and 5.

In Figs. 4 and 5, batteries "B" and 100 are connected in series in the plate circuit of detector 94 and both contribute to the detector plate current. The "B" battery supplies the voltage drop in resistor 101, while battery 100 supplies the plate voltage of detector 94. The presence in the detector plate circuit of the "B" battery, which is directly connected to the grounded filament circuit, in addition to auxiliary battery 100, allows the use of a high impedance 101 in the detector plate circuit with a resulting high sensitivity of the detector circuit. The same result is achieved in the arrangement of Fig. 6 by the cooperation of the "A" and "B" voltages in the detector plate circuit, as described before. In the event that tubes having an indirectly heated cathode are used instead of those having an incandescent filament cathode as represented in the figure, the same advantages may be obtained as pointed out in connection with Fig. 6, if the detector cathode is maintained at a potential much more negative than the cathode of the controlled tube or tubes, which, in the figure, is the first radio-frequency amplifier tube.

The circuit arrangement shown in Fig. 7 incorporates several advantages introduced by the present invention, some of which have been individually described above. Briefly, this arrangement includes a combination of the features illustrated in and described in connection with Fig. 3 and Fig. 6. The reference characters of Fig. 7 correspond to those employed in Fig. 3 and have the same significance. It will be noted in addition to the apparatus represented in Fig. 3, that

there is here illustrated a power source of rectified and filtered alternating current which replaces the so-called "A" and "B" batteries represented in Fig. 3, and in addition, includes a source of "C," or grid bias voltage for tube 79. The grid of tube 77 is biased by connecting the "grid return lead" to an appropriate point in the series filament circuit, as shown. The power source is similar to that shown in and described in connection with Fig. 6. The present arrangement thus includes the advantages of neutralized radio-frequency amplifying stages, automatic volume control applied to the first two stages of the radio-frequency amplifier, a two-electrode valve, or rectifier, and the complete elimination of all batteries for supplying operating potentials to the system. As is also true of the arrangement of Fig. 6, the automatic volume control not only compensates for fluctuations in the strength of the incoming signals, but also compensates for reasonable variations in line voltage of the alternating current power supply.

As in Fig. 6 the variable tuning condensers C_1—C_4 are grounded in order to eliminate undesirable capacity effects as well as to make it practicable to connect the condensers on a single shaft for uni-control, if desired. As in Fig. 6, it will be seen that the power supply of Fig. 7 is not grounded, thus eliminating the danger of short-circuiting the direct current supply when a separate ground is necessary for the alternating-current rectifying and filtering system. In certain instances, Figs. 6 and 7 differ in the connection of certain by-pass condensers. The purposes and reasons for the positions of these by-pass condensers should be apparent to those skilled in the art.

Assuming that the vacuum tubes employed are of the type having five-volt filaments, 35 volts of filament, or "A", supply is needed. As above mentioned, the automatic volume control is here applied to two tubes, namely 58 and 60; the cut-off being effected with the use of two different plate, or "B", voltages. The plate electrode 66 of rectifier 64 is more negative relative to the filament of tube 58 than relative to the filament of tube 60, by the 5-volt drop across one filament. To compensate for this difference, 35 volts higher "B" voltage is applied to the plate of tube 58 than to the plate of tube 60, which makes both tubes cut off practically at the same time. The reason for applying a "B" voltage of 85 volts (which, of course, is to be added to the 35 volts "A" voltage) to the plate of tube 60, whereas a "B" voltage of 90 volts is applied to the plates of the radio-frequency amplifying tubes of Fig. 6, is that the arrangement of Fig. 7 employs one more tube than Fig. 6; the difference of 5 volts being included in the "A" supply, as will be seen by comparing the two figures. Thus, actually, the plates of the radio-frequency amplifying tubes 119, 120 and 121 of Fig. 6 are provided with 90, 95 and 100 volts, respectively. Similarly the plates of the amplifying tubes of Fig. 7 are supplied with 85 to 155 volts.

In addition to the combined advantages just outlined, the arrangement of Fig. 7 also includes an additional feature which has not previously been described, namely, the means 130 for determining the filament current supplied to one of the amplifying tubes. As has been explained in connection with Fig. 6, when operating the filaments of the several vacuum tubes on rectified and filtered current from an alternating current power source, it is desirable that the filaments be connected in series since it is at present more practicable to provide a current supply at a comparatively high voltage and low current. Fig. 6 shows a shunt rheostat 129 connected in parallel with the filament of tube 125 so that the current divides between the rheostat and the filament. While this means for controlling the filament emission of a single tube, as shown in Fig. 6, is fairly satisfactory, the arrangement shown in Fig. 7 is a substantial improvement. With the former method, an increase in current through the controlled filament is accompanied by a smaller increase in current through the other filaments in series. The improved arrangement shown in Fig. 7, on the other hand, by providing three resistances, two of which are simultaneously variable, allows a variation of the voltage on one or more filaments without affecting the current through the other filaments; or, more generally, without changing the load on the filament-current supply. It is apparent that the benefits of this device will be especially manifest in an arrangement such as the present, wherein the current supply for the filaments is obtained from a rectified, filtered alternating current source, particularly when the rectifying device is of the common type without automatic voltage regulation. The compound rheostat 130 comprising resistances R_1 and R_2 is so arranged that a movement of the control knob will increase the one resistance, while diminishing the other in proportion. One of these resistances, namely R_1 is connected in series with resistance R_s in shunt with filament 74 of tube 71, the resistance of filament 74 being represented by "R_f". It may here be pointed out that while Fig. 7 illustrates the manual control of the filament of only one tube, namely 74, the filaments of other tubes could be connected either in series or parallel with filament 74 if it were desired that independent simultaneous control be had of more than one filament. "R_f," may, therefore, be taken to represent the effective resistance of the filaments to be controlled. When the two resistances R_1 and R_2 and the fixed resistance

R_2 are properly proportioned to the normal operating resistance R_f of the filament or filaments of the tubes to be controlled, the resistance of the system as a whole will remain substantially constant during adjustment of the control device 130. By way of illustration, the following data are given for Fig. 7, assuming the tubes to be all of the well-known 201A type, each filament being of 20 ohms resistance: R_f will equal 20 ohms; R_2 may equal R_f; R_1 may equal $8R_f$; and R_3 may equal $\frac{1}{2}R_f$. Accordingly, to control one tube when R_f equals 20 ohms, R_2 will equal 20 ohms, R_1 will equal 160 ohms, and R_3, 10 ohms.

It is believed unnecessary to describe the method of controlling the signal amplification in the arrangements of Figs. 5, 6 and 7 since they are substantially similar in operation to that of the systems described in reference to Figs. 1, 3 and 4. It should be mentioned, however, that the advantages of the present invention are especially apparent in systems such as shown in Figs. 6 and 7, because of the fact that any reasonable fluctuations in the voltage of the power supply line are thus automatically compensated for, and uniform volume of signals is assured.

There are advantages attending the use, in connection with the present invention, of the two-electrode rectifier circuit typified by Figs. 1, 3 and 7, which may not be apparent from the foregoing discussion. It is impossible to overload this type of rectifier, and the rectified output voltage is directly proportional to the applied alternating signal voltage when this voltage is large, say over two volts. The control system in the circuits of the figures referred to requires a large operating voltage, say ten volts, so that the latter condition of large signal voltage is realized. No such simple relationship is possible in a three-electrode detector, whose rectified output never exceeds a limiting upper value, and is never proportional to the applied voltage, except over a very small range of voltages. This distinction will be seen from Fig. 8 where the abscissæ "A. C." represent the alternating signal voltages, whereas the ordinates "D. C." represent the rectified output voltages. It is well known that the linear curve is much more desirable when minimum distortion of a modulated signal is desired, and it will be observed from Fig. 8 that the preferred type of curve is obtained from the two-electrode rectifier.

A further advantage of the "linear" type detector with the automatic volume control connection and a visual resonance indicator in the anode circuit of the amplifier whose grid bias is being automatically controlled, lies in the fact that the visual resonance indicator will give an indication which is proportionate to the received signal intensity. This follows from the fact that the negative grid bias on the amplifier is directly proportional to the strength of the signal; and hence the anode current bears a similar relation to the signal.

The three-electrode detector is useful for relatively small applied voltages, and the rectified output voltage is then approximately proportional to the square of the applied voltage, i. e., to the power associated with the applied voltage. For this reason the rectified voltage increases with the carrier wave modulation. When such a detector is used in the control system, as in Figs. 4, 5 and 6, the total power from the radio-frequency amplifier is maintained at a substantially constant level, the amplitude of the carrier wave being decreased in the presence of modulation. It is desirable to maintain the carrier wave at a constant amplitude at the output of the amplifier, and this is accomplished by the two-electrode rectifier as shown in Figs. 1, 3 and 7. The control system maintains constant the average signal amplitude which is equal to the carrier wave amplitude and independent of the degree of modulation.

It will be observed that in a system employing a two-electrode rectifier such as represented by valve 33 of Fig. 1, and 64 of Figs. 3 and 7, the control bias voltage is independent of the "B" or anode battery voltage. Since the rectifier is not an amplifier, is not critical, and requires neither anode nor biasing battery, no adjusting devices are required. This is not the case in the three-electrode detector circuits, so that a potentiometer, 98 or 128 in Figs. 4 or 6, respectively, must be adjusted as described to accommodate the control bias to any particular combination of tubes and "B" voltage. On the other hand, the latter type of detector is more sensitive because it is also an amplifier, so that the control system operates on a smaller applied alternating voltage.

In the foregoing description, tuned radio-frequency receivers of the neutralized and unneutralized types have been referred to. It should be pointed out, however, that the present invention may be employed with equal effectiveness to any radio receivers in wired radio and space radio systems, and that it has been found especially applicable to receivers of the super-heterodyne type. For this reason the present disclosure of typical embodiments of the invention should not be construed as a limitation, but merely as illustrative of the principles of the invention, the scope of which is defined in the appended claims.

What is claimed is:

1. In a signaling system a vacuum tube amplifier having a cathode and a control electrode, a vacuum tube detector coupled to said amplifier, said detector having an output electrode, means for maintaining said out-

put electrode normally negative relative to at least part of said amplifier cathode, means for causing said output electrode to become more negative in the presence of an amplified signal, and a direct-current connection between said control electrode and said output electrode, whereby the amplification of said amplifier is regulated automatically.

2. In a carrier-current signaling system, in combination, a vacuum tube amplifier having a cathode and a control electrode, a vacuum tube detector coupled directly to the output of said amplifier, said detector having a cathode and an output electrode, means for maintaining said detector cathode at substantially the same potential as said amplifier cathode, means for maintaining said output electrode at a negative potential with respect to said cathodes, means causing said output electrode to become more negative in the presence of an amplified signal, and a direct-current connection between said output electrode and said control electrode.

3. A combination according to claim 2 in which the means for maintaining the detector output electrode at a negative potential with respect to said cathodes is a resistance connected between said output electrode and the detector cathode.

4. In a modulated carrier-current signalling system employing a carrier-current amplifier and rectifier, which rectifier produces a modulated uni-directional voltage, a direct-current connection from said rectifier to an element of said amplifier whereby the amplification is regulated automatically, and a connection from said rectifier to a modulation current amplifier whereby the signal is further amplified, said connection from said rectifier to said modulation current amplifier including a condenser in series for preventing the uni-directional component from being impressed upon the input of said modulation current amplifier.

5. In a signaling system, a vacuum tube amplifier having a cathode and a control electrode, a detector coupled to said amplifier, said detector having an output electrode, means for maintaining said output electrode normally negative relative to at least part of said amplifier cathode, means for causing said output electrode to become more negative in the presence of an amplified signal, and a direct-current connection between said control electrode and said output electrode, whereby the amplification of said amplifier is regulated automatically.

6. In a signaling system a vacuum tube amplifier having a cathode and a control electrode, a second vacuum tube having an output electrode, means for coupling the output of said amplifier with said second tube, means for maintaining said output electrode normally slightly negative relative to at least part of said cathode, means for causing said output electrode to become more negative in the presence of an amplified signal, and a direct-current connection between said control electrode and said output electrode, whereby the amplification of said amplifier is regulated automatically.

7. In a signaling system, a vacuum tube amplifier having an anode, a cathode and a control electrode, a detector coupled to said amplifier, said detector having an output electrode, means for maintaining said output electrode normally negative relative to at least part of said amplifier cathode, means for causing the said output electrode to become more negative in the presence of an amplified signal, a tuning arrangement for tuning said amplifier to a desired signal, a direct current connection between said control electrode and said output electrode, whereby the amplification of said amplifier is regulated automatically, and means for visually indicating the condition of resonance in said tuning arrangement, whereby tuning is facilitated.

8. An arrangement according to claim 7 in which said tuning arrangement and said means for visually indicating the condition of resonance are connected in the anode circuit of said amplifier.

9. In a signaling system a vacuum tube amplifier having a cathode and a control electrode, a vacuum tube detector coupled to the output of said amplifier, said detector having a cathode and an output electrode, means for maintaining said detector cathode at a potential greatly negative relative to said amplifier cathode, means for maintaining said output electrode at a potential normally slightly negative relative to said amplifier cathode, means for causing said output electrode to become more negative in the presence of an amplified signal, and a direct-current connection between said output electrode and said control electrode whereby the amplification of said amplifier is regulated automatically.

10. In a signaling system, a vacuum tube amplifier having a cathode and a control electrode, a diode detector coupled to said amplifier, said detector having an anode, means for maintaining said anode normally negative relative to at least part of said amplifier cathode, means for causing said anode to become more negative in the presence of an amplified signal, and a direct-current connection between said control electrode and said anode, whereby the amplification of said amplifier is regulated automatically.

11. In a signaling system, a vacuum tube amplifier having a cathode and a control electrode, a diode detector coupled to said amplifier, said detector having a cathode and an anode, means for maintaining said cathodes at substantially the same potential, means including a high resistance connected

between the detector anode and cathode for maintaining said anode normally slightly negative relative to said cathodes, means for causing said anode to become more negative in the presence of an amplified signal, and a direct-current connection between said control electrode and said anode, whereby the amplification of said amplifier is regulated automatically.

12. In a signaling system a vacuum tube amplifier having a cathode and a control electrode, a second vacuum tube having an output electrode, means for coupling said amplifier with said second tube, means for maintaining said output electrode normally slightly negative relative to at least part of said cathode, means for causing said output electrode to become more negative in the presence of an amplified signal, a tuning arrangement for tuning said amplifier to a desired signal, and a direct-current connection between said control electrode and said output electrode, whereby the amplification of said amplifier is regulated automatically, and means for visually indicating the condition of resonance in said tuning arrangement whereby tuning is facilitated.

In testimony whereof I affix my signature.
HAROLD A. WHEELER.

Div. 51 Room 5628 Paper No. 7

Address only "The Commissioner of Patents, Washington, D. C." and not any official by name HSM:MCG

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON

All communications respecting this application should give the serial number, date of filing, and name of the applicant

July 19, 1935.

Please find below a communication from the EXAMINER in charge of this application.

Commissioner of Patents.

Applicant: Harold A. Wheeler
Ser. No. 745,651
Filed Sept. 26, 1934
For Volume Control

Pennie, Davis, Marvin & Edmonds,
165 Broadway,
New York, N. Y.

Responsive to applicant's communications of February 1[illegible], and May [illegible], 1935.

The reissue oath has been carefully reviewed in the light of recent decisions, particularly that of Union Switch and Signal Co. v. Louisville Frog Switch and Signal Co. 452 O. G. 255 73 Fed. (2nd) 550. The oath is insufficient since it merely alleges that the patent is insufficient and inoperative by reason of the failure to make certain claims and that the error arose through inadvertence, accident or mistake but does not specify the errors which constitute the inadvertence, accident or mistake.

The claims are rejected on the grounds above set forth.

Examiner

9-3871

PAPER NO. 8
AMENDMENT B

B 704

SEP 7 1935 IN THE UNITED STATES PATENT OFFICE

In re application of

HAROLD A. WHEELER

Serial No. 745,651

Filed September 26, 1934

Reissue of Patent No. 1,879,863

Div. 51 - Room 5628

OR: VOLUME CONTROL

New York, N.Y., August 31, 1935

Honorable Commissioner of Patents,

Wa[redacted]on, D.C.

Sir:

Receipt of the Office action of July 19, 1935 is acknowledged. Please amend as follows:

Page 4, line 23, after "employed" insert --is a two-electrode rectifier which--;

line 24, cancel "two-electrode".

Page 6, line 22, cancel the comma after the word "invention" and the words "means are provided to control automatically"; and in line [illegible] after the word "[illegible]" cancel the period and insert --[illegible] controlled by a biasing potential [illegible] modulated signal carrier in a two-electrode rectifier [illegible] having--;

line [illegible], cancel the words "[illegible] include" and at the end [illegible];

Page 7, line 4, [illegible] --[illegible] tubes--;

Page [illegible], line [illegible], insert [illegible] before "detector" and [illegible]

line [illegible], insert [illegible] before "radio-frequency".

Page 11, line [illegible], change [illegible] to --rectifier--.

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Page 15, line 27, change "valve" to --tube--; after "required." in line 32, insert --This is not the case in three-electrode detector circuits in which an adjustment must be made, as by a potentiometer, to accommodate the control bias to any particular combination of tubes and "B" voltage.--

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Cancel claims 1, 5, 6 and 12.

Claim 4, line 1, change "modulated carrier-current" to --modulated-carrier--; change "signaling" to --signal--;

line 2, change "system employing" to --receiver having--; change "current" to --frequency--; strike out "and" and insert --, a two-electrode--; after "rectifier" and before the comma insert --coupled to the output circuit of said amplifier--;

lines 7, 9 and 12, change "modulation current" to --modulation-frequency--.

Claim 7, line 1, cancel "signaling system, a" and insert --modulated-carrier signal receiver having a carrier-frequency amplifier adapted to amplify modulated signals prior to detection, which amplifier has means for tuning to a desired signal and includes at least one amplifier--; cancel "amplifier";

line 2, cancel "an anode,";

lines 2-4 inclusive, cancel ", a detector coupled to said amplifier, said detector having an output electrode," and insert --and possessing the property that its amplification decreases with increasingly negative biasing potential on said control electrode relative to the cathode; a system of automatic amplification control which includes a two-electrode rectifier coupled to the output circuit of the amplifier by means no more selective than the

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amplifier, a high resistance connected between the rectifier anode and said amplifier cathode,--;

line 4, after "means" insert --including said resistance--;

lines 4 and 5, cancel "said output electrode" and insert --the average potential of said anode--;

lines 6 and 7, cancel ", means for causing the said output electrode to become more" and insert --and increasingly--;

line 7, cancel "in the presence of an" and insert --with increasing--;

line 8, after "signal" insert --output from said amplifier--;

lines 8 and 9, cancel "a tuning arrangement for tuning said amplifier to a desired signal,";

line 9, hyphenate "direct current";

line 10, cancel "between said" and insert --from said anode back to said amplifier--; cancel "and said output electrode," and insert --for impressing thereon a negative potential which varies in accordance with the average potential of said anode,--;

line 11, after "the" insert --carrier-frequency--; change "of" to --in--; change "regulated" to --substantially decreased--;

lines 12-14, cancel ", and means for visually indicating the condition of resonance in said tuning arrangement, whereby tuning is facilitated:" and insert --with increasing amplified signal output from said amplifier, and a visual indicator coupled to the output circuit of the amplifier and responsive to the relative magnitude of said output, whereby the visual indication follows the strength of the

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detected signal and thereby facilitates tuning.--

Claim 8, line 2, cancel "means for"; change "visually" to --visual--; change "indicating" to --indicator--;

lines 2 and 3, cancel "the condition of resonance";

line 4, after "amplifier" insert --vacuum tube--.

Claim 9, line 1, cancel "signaling system, a vacuum tube" and insert --signal receiver having [illegible]-frequency--; after "amplifier" insert --which includes at least one vacuum tube--;

line 2, cancel "diode detector" and substitute --two-electrode rectifier--;

line 3, after "to" insert --the output circuit of--; cancel "said detector having an anode," and insert --a high resistance connected between the rectifier anode and the amplifier cathode,--;

line 4, after "means" insert --including said resistance--; after "maintaining" insert --the average potential of--;

lines 5 and 6, cancel "means for causing said anode to become more" and substitute --and increasingly--

lines 6 and 7, cancel "in the presence of an" and substitute --with increasing--;

line 7, after "signal" insert --[illegible] from said amplifier--.

line 8, cancel "between" and substitute --from said anode back to--; before "control" insert --amplifier--; cancel "and said anode".

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Claim 11, line 1, cancel "signaling system a" and insert --modulated-carrier signal receiver having a carrier-frequency amplifier adapted to amplify modulated signals prior to detection, which amplifier has means for tuning to a desired signal and includes at least one amplifier--; cancel "amplifier";

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line 2, after "electrode" cancel ", a" and insert --and possessing the property that its amplification decreases with increasingly negative biasing potential on said control electrode relative to the cathode; a system of automatic amplification control which includes a second vacuum tube coupled to the output circuit of the amplifier by means no more selective than the amplifier, said--;

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lines 3 and 4, cancel "means for coupling said amplifier with said second tube,";

line 4, after "maintaining" insert --the average potential of--;

(first occurrence)

line 6, after "said" insert --amplifier--;

lines 6 and 7, cancel ", means for causing said output electrode to become more" and insert --and increasingly--;

lines 7 and 8, cancel "in the presence of an" and insert --with increasing--; after "signal" insert --output from said amplifier--;

lines 8 and 9, cancel "a tuning arrangement for tuning said amplifier to a desired signal, and";

line 10, cancel "between said control electrode and" and insert --from--;

line 11, after "electrode" insert --back to the amplifier control electrode for impressing thereon

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a negative biasing potential which varies in accordance with the average potential of said output electrode--; after "the" insert -carrier-frequency--; change "of" to --in--;

line 12, change "regulated" to --substantially decreased--;

lines 12 to 14 inclusive, cancel ", and means for visually indicating the condition of resonance in said tuning arrangement whereby tuning is facilitated" and insert --with increasing amplified signal output from said amplifier, and a visual indicator coupled to the output circuit of the amplifier and responsive to the relative magnitude of said output, whereby the visual indication follows the strength of the detected signal and thereby facilitates tuning--.

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Claim 13, line 1, cancel ", a" and substitute --having--;

line 2, cancel "including" and substitute --adapted to amplify modulated signals prior to detection, which amplifier has means for tuning to a desired signal and includes--;

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lines 2 and 3, cancel "vacuum tube for amplifying a desired signal, said";

line 4, cancel "having";

lines 4 and 5, cancel "for reducing the amplification in said tube" and substitute --and possessing the property that its amplification decreases--;

line 5, change "increasing" to --increasingly--;

line 6, change "voltage" to --potential--; after "electrode" cancel ", a" and insert --relative to

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the cathode; a system of automatic amplification control which includes a second vacuum tube coupled to the output circuit of the amplifier by means no more selective than the amplifier, said--;

line 10, after "maintaining" insert --the average potential of--;

line 11, after "cathode" cancel the comma;

lines 12, 13 and 14, cancel "means for causing said space current to vary in the direction to cause the average voltage of said output electrode to become more negative in response to" and insert --and increasingly negative with--;

line 18, change "voltage" to --potential-- (both occurrences);

line 21, after "resistance" insert --in said direct-current connection--;

line 22, cancel "in said direct-current connection";

line 23, after "of" insert --signal--;

line 24, cancel "of said amplified signal output";

line 26, change "reduced" to --decreased--;

line 27, after "amplifier" insert --and

B13 the detected signal strength is automatically controlled irrespective of whether the amplifier is exactly in tune with the signal carrier--.

Claim 14, line 1, cancel "radio" and insert --modulated-carrier signal--;

lines 1 and 2, cancel "an antenna circuit for intercepting modulated-carrier signals of a wide range of amplitude and frequency," and insert --having--;

line 4, cancel "including" and insert

B14 --adapted to amplify modulated signals prior to detection,

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which amplifier has means for tuning to a desired signal and includes--;

lines 4 to 7, cancel "vacuum tube for amplifying and at least one circuit tunable over said frequency range for selecting any desired one of said signals from said antenna circuit, said";

line 8, cancel "having";

lines 8 and 9, cancel "for reducing the amplification in said tube" and insert --and possessing the property that its amplification decreases--;

line 9, change "increasing" to --increasingly--; change "voltage" to --potential--;

lines 10 and 11, change ", a vacuum tube detector having an anode whose space current circuit includes" to --relative to the cathode; a system of automatic amplification control which includes a two-electrode rectifier coupled to the output circuit of the amplifier by means no more selective than the amplifier, a high--;

line 12, cancel "said" (first occurrence) and insert --the rectifier--;

line 13, after "maintaining" insert --the average potential of--;

lines 15-19 inclusive, cancel ", means for coupling the amplified signal output from said amplifier to said detector, means for causing said space current to increase and thereby to cause the average voltage of said anode to become more negative in response to" and insert --and increasingly negative with--;

lines 22 and 23, change "voltage" to --potential--;

line 25, after "resistance" insert --in said direct-current connection--;

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line 26, cancel "in said direct-current connection";

line 28, before "modulation" insert --signal--;

lines 28 and 29, cancel "of said amplified signal output";

line 30, change "reduced" to --decreased--;

line 32, after "amplifier" insert --and the detected signal strength is automatically controlled irrespective of whether the amplifier is exactly in tune with the signal carrier--.

Claim 15, line 1, after "receiver" cancel the comma and insert --having--;

line 2, cancel "including" and insert --which includes--;

lines 2 and 3, cancel "vacuum tube for amplifying a desired signal, said";

line 4, cancel "having" (second occurrence);

lines 4 and 5, cancel "for reducing the amplification in said tube" and insert --and possessing the property that its amplification decreases--;

line 5, change "increasing" to --increasingly--;

line 6, change "voltage" to --potential--;

lines 6-8, cancel ", a diode detector having a cathode and an anode with resistance connected therebetween" and insert --relative to the cathode; a system of automatic amplification control which includes a two-electrode rectifier coupled to the output circuit of the amplifier, a high resistance connected between the rectifier anode and said amplifier cathode--;

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line 9, after "maintaining" insert --the average potential of--;

lines 1[illegible]-13 inclusive, cancel ", means for coupling the amplified signal output from said amplifier to said detector and thereby causing the average voltage of said anode to become more" and insert --and increasingly--;

line 13, cancel "in response to" and insert --with--;

line 17, change "voltage" to --potential-- (both occurrences);

line 20, after "resistance" insert --in said direct-current connection--;

lines [illegible] and [illegible], cancel "in said direct-current connection";

line [illegible], before "modulation" insert --signal--; after "modulation" cancel "of said amplified signal output";

line [illegible], change "reduced" to --decreased--.

Claim 16, line 1, cancel the comma and insert --having--;

line 2, change "including" to --which includes--;

lines 2 and 3, cancel "vacuum tube for amplifying a desired signal, said";

line 4, cancel "having" (second occurrence);

lines 4 and 5, cancel "for reducing the amplification in said tube" and insert --and possessing the property that its amplification decreases--;

line 5, change "increasing" to --increasingly--;

line 6, change "voltage" to --potential--;

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lines 6-8 inclusive, cancel ", a diode detector having a cathode and an anode with resistance connected therebetween," and insert --relative to the cathode; a system of automatic amplification control which includes a two-electrode rectifier coupled to the output circuit of the amplifier,--;

line [illegible], change "said" to --the--;

line 9, change "detector" to --rectifier--; after "potential," insert --a high-resistance connected between the anode and the cathode of the rectifier,--;

line [illegible], after "maintaining" insert --the average potential of--;

lines [illegible]-14, cancel ", means for coupling the amplified signal output from said amplifier to said detector and thereby causing the average voltage of said anode to become more" and insert --and increasingly--;

line 15, cancel "in response to" and insert --with--;

lines [illegible] and [illegible], change "voltage" to --potential--;

line 21, after "resistance" insert --in said direct-current connection--;

line [illegible], cancel "in said direct-current connection";

line [illegible], before "connection" insert --signal--;

line [illegible], cancel "of said amplified signal output";

line 26, change "reduced" to --lessened--.

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Claim 17, line 1, cancel the comma and insert --having--;

line 2, change "including" to --which includes--;

lines 2 and 3, cancel "vacuum tube for amplifying a desired signal, said";

line 4, cancel "having" (second occurrence);

lines 4 and 5, cancel "for reducing the amplification in said tube" and insert --and possessing the property that its amplification decreases--;

line 5, change "increasing" to --increasingly--;

line 6, change "voltage" to --potential--;

lines 6-8 inclusive, cancel ", a diode detector having a cathode and an anode with resistance connected therebetween" and insert --relative to the cathode, said receiver also having a modulation-frequency amplifier which is coupled to a signal reproducer, a system of automatic amplification control which includes a two-electrode rectifier coupled to the output circuit of the amplifier, a high resistance connected between the rectifier anode and said amplifier cathode--;

line [illegible], after "maintaining" insert --the average potential of--;

lines [illegible] inclusive, cancel ", means for coupling the amplified signal output from said amplifier to said detector and thereby causing the average voltage of said anode to become more" and insert --and increasingly--;

line [illegible], cancel "in response to" and insert --with--;

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line 14, before "amplifier" insert --carrier-frequency--;

line 17, change "voltage" to --potential-- (both occurrences);

line 20, after "resistance" insert --in said direct-current connection--;

lines 20 and 21, cancel "in said direct-current connection";

line 23, before "modulation" insert --signal--; after "modulation" insert --, whereby the carrier-frequency amplification is substantially decreased with increasing amplified ~~signal output from said~~ carrier-frequency amplifier--; cancel "of said amplified signal output";

line 24, change "current" to --frequency--; change "a" to --the--;

line 25, change "current" to --frequency--; after "amplifier" insert --, whereby the rectifier serves also for signal detection--;

lines 25 and 26, cancel "and reproducer whereby the signal is further amplified and reproduced";

line 27, after "the" insert --modulation-frequency-- and cancel "amount of said carrier";

lines 27-30 inclusive, cancel "whereby the carrier-frequency amplification in said amplifier is substantially reduced automatically with increasing amplified signal output from said amplifier and";

line 30, before "the" insert --whereby--;

line 31, after "at" insert --any desired--;

lines 31 and 32, cancel "determined by said adjustable means".

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REMARKS

This application for reissue was filed on September 26, 1934 for the purpose of correcting defects and insufficiencies in the original specification and claims of which the patentee had become apprised as a result of the decision of the District Court in the case of Hazeltine Corporation vs. Benjamin Abrams and Davega City Radio, Inc. The decision of the District Court has now been affirmed by the Court of Appeals of the Second Circuit (opinion by Judge Learned Hand) and the Examiner has had a copy of that opinion. The purpose of the foregoing amendment is to complete the correction of the specification and to restrict the claims, in the light of that opinion.

In redrawing the claims we have sought to expressly restrict them to the novel and patentable combination and arrangement of parts that characterizes Mr. Wheeler's particular way of securing automatic volume control in modulated-carrier signal receivers. We intend to eliminate, once for all, the thought that a monopoly is claimed for all applications of automatic volume control to radio receivers; and the thought that the asserted patentability rests merely upon the conception of applying automatic volume control to a radio receiver. It is sought to present claims the patentability of which may be tested by a comparison of Mr. Wheeler's particular way of securing automatic volume control in such a receiver, with other possible ways of securing automatic volume control. We believe that each of the claims now presented, when subjected to that test, will be found to define a particular way of effecting automatic volume control not previously known and not within the reach of mere engineering skill.

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In the automatically controlled signal receiver devised by Mr. Wheeler, the automatic control of amplification is effected by a biasing potential obtained by rectifying a signal carrier in a two-electrode rectifier.

In the years following 1920, vacuum-tube detectors were of the three-electrode type, which had superseded the two-electrode type. The three-electrode type was proposed for use in automatic bias-control of carrier-frequency amplification (Hazel Patent No. 1,511,015).

Wheeler appreciated the inherent disadvantages of a three-electrode rectifier used for this purpose. The disadvantages included (1) circuit complication and (2) unreliable and imperfect operation.

1. Circuit complication. A three-electrode rectifier requires [illegible] for the [illegible] for [illegible] to the electrodes in addition to the [illegible] for the [illegible] for rectifying. [illegible] batteries were [illegible] and expensive. [illegible]

[illegible]

2. [illegible] rectifier [illegible] critical [illegible] relatively [illegible]

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Also the three-electrode rectifier for bias-control was unresponsive to small signal input voltages, but was overloaded by moderately large signal voltages. Therefore the useful range of signal voltages was within close limits; and it was difficult to maintain the signal voltage within these limits. Broadcast receivers are not operated under favorable technical circumstances; [illegible] vary in voltage from the nominal [illegible] tubes may be replaced by others of somewhat different characteristics; [illegible] users are [illegible] unskilled. [illegible]

[illegible]

The two-electrode type of rectifier in the form known as the Fleming valve had been employed for signal

[redacted]

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ohms) in place of the telephone or the transformer primary (ranging from about 1000 to 5000 ohms) then customarily used in the output circuit of a radio detector, whether a Fleming valve or a three-electrode detector. The two-electrode rectifier with this high resistance in the output circuit is capable of producing the requisite potential of the order of 10 volts, provided that adequate amplification is effected ahead of the rectifier.

(b). The two-electrode rectifier, deriving its power from the signal which it receives and not from a separate source (plate circuit supply) as in the three-electrode rectifier, had the further limitation that it placed a load on the preceding amplifier stage, which detracted both from amplification and from selectivity. The high resistance introduced by Wheeler in the output circuit of the two-electrode rectifier minimized this load to a point where it could be disregarded.

The two-electrode rectifier in the circuit thus modified by Mr. Wheeler had definite advantages for [illegible] control which were in contradistinction to the corresponding disadvantages of the three-electrode rectifier for this purpose. The advantages were (1) circuit simplification and (2) reliable and perfect operation.

1. Circuit Simplification. The two-electrode rectifier required no "B" and "C" batteries for the equivalent [illegible] only the signal voltage is applied between its electrodes. The anode assumed the proper

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potential for biasing the carrier-frequency amplifier and thereby controlling the amplification therein. The resulting non-critical operation [illegible] made it practical to utilize the same rectifier for signal detection as well as for bias-control.

2a. Reliable Operation. The two-electrode rectifier was entirely non-critical in its operation, being independent of battery voltages and practically free of any overloading effects. The latter property made possible the advantageous employment of much amplification ahead of the rectifier, thus impressing on the rectifier signal voltages in the order of 1[illegible] volts. The rectifier operated very efficiently on such voltages, so that rectified voltages in the order of ten volts were available for bias-control; and such voltages were sufficient for reliable operation of the control.

2b. Perfect Operation. When the two-electrode rectifier in the circuit was operated on such large signal voltages, substantially the ideal "linear" [illegible] was realized. The undesired influence of the three-electrode rectifier with its "square-law" operation was removed. [illegible] became independent of [illegible] of the signal. "Linear" operation is [illegible] in [illegible] signal detector, and [illegible] realized in the [illegible] of the improved two-electrode rectifier as the signal detector.

Wheeler's two-electrode rectifier with the resistance in the output circuit opened up, furthermore, other possibilities of improvement in amplification control in

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a radio receiver, of which Wheeler took advantage by further inventive steps. The essentially linear operation of the new arrangement, in which the control bias was independent of the modulation components of the signal, made it possible to impress the <u>modulated-carrier</u> on the rectifier, instead of first removing the modulation by a sharply tuned carrier selector, as was considered necessary when a three-electrode rectifier was used (Affel and Friis). It was only necessary, in the new arrangement, to filter out the modulation fluctuations in the rectified voltage before applying the rectified voltage to the control grid of the amplifier; and this Wheeler did by combination of a condenser and a resistance having a suitable time constant. From this forward step the important advantage resulted that the signal was subject to amplification control whenever the amplifying circuits were closely enough in tune with the carrier to amplify; while in the previous three-electrode systems having a filter sharply tuned to the carrier interposed between the amplifying circuits and the rectifier, the signal was not subject to amplification control until the amplifier was closely tuned to the carrier, and an unobjectionably loud, harsh response (blasting) would be heard whenever, during the manipulation of the receiver to select a particular signal, the receiver was not quite in tune.

Finally, Wheeler's use of the same rectified voltage for control and for delivery to the loud-speaker permitted him to associate with the control a visual indicator of resonance conditions that would follow the repro-

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duced signals, changing gradually to an extreme indication as resonance was approached. In an automatic amplification control system employing a sharply tuned carrier selector, a visual resonance indicator would be of little utility; for if it were connected to the amplifier anode circuit, it would not respond until the receiver had been brought into practically exact resonance, which would already have been made evident audibly by a sharp reduction in loudness and a clarification of the signal; while if it were connected in the detector anode circuit, it would first show a rise and then a fall as resonance was approached, like the audible response; and the behavior in each case would be so awkward to the unskilled user as not to constitute a desirable feature. The use of a visual resonance indicator, generally desirable when applicable, is of especial utility in Wheeler's automatic amplification control system, where the loudness of a strong received signal varies slowly with the tuning, in the neighborhood of resonance, the ear being very insensitive to such small changes in sound intensity.

It is apparent that the availability and the cooperative relationship of elements in the novel combination devised by Mr. Wheeler is affected by the nature of the particular environment (amplifying receiver) to which the invention is applied. For this reason the long claims 7, 9, 11 and 15 to 17 have been formulated with a preamble describing this environment, followed by the body of the claim in which is recited the elements whose combination makes up the invention, and concluded by a statement of the result attained. It is believed that the new preambles and concluding state-

Serial No. [illegible]

[illegible]nts will speak for themselves without further [illegible]cussion. But for the convenience of [illegible] amended claims we add here a comparison of the [illegible] as now amended [illegible] with [illegible] 1, [illegible] amended, which have been held invalid [illegible] as [illegible] presented in the [illegible] applicants [illegible]

[illegible]

[illegible]

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vacuum tube") is coupled to the output circuit of the amplifier by means "no more selective than the amplifier" and the visual indicator is also "coupled to the output circuit of the amplifier". This gives the advantage that the visual indication "follows the strength of the desired signal and thereby facilitates tuning".

The combination defined in claim [illegible] as amended includes "a high resistance connected between the amplifier anode and the [illegible]". [illegible]

[illegible]

[illegible] selective than the amplifier [illegible]

[illegible] electrode (anode) positive [illegible]

[illegible] high resistance connected [illegible]

[illegible] amplifier cathode". [illegible]

[illegible] negative potential [illegible]

[illegible]

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In claims 15, 16 and 17, the "noise detector" has been termed a "two-electrode rectifier", as in claim [illegible]. The resistance between the rectifier anode and the rectifier cathode is limited as being "high".

This application is now believed to be in condition for allowance and such favorable action is [illegible] respectfully requested.

Respectfully submitted,

C-3871

SEP 5 [illegible]

IN THE UNITED STATES PATENT OFFICE

In re application of	)	
HAROLD A. WHEELER	)	
Serial No. 745,651	)	
Filed September 26, 1934	)	FOR: VOLUME CONTROL
Reissue of Patent No. 1,879,863	)	
Div. 51 - Room [illegible]	)	

AMENDED AND SUPPLEMENTAL OATH

STATE OF NEW YORK	)	
	)	ss:
COUNTY OF NEW YORK	)	

HAROLD A. WHEELER, the above-named petitioner, whose application for reissue of Letters Patent for an improvement in Volume Control, Serial No. 745,651 was filed in the United States Patent Office on or about the 26th day of September, 1934, being duly sworn, deposes and says:

that he does verily believe himself to be the original, first and sole inventor of the improvement set forth and claimed in the specification and drawings filed herein September 26, 1934 [illegible] filed herein [illegible] con-temporaneously herewith, [illegible] patented [illegible] the said improvement was ever before [illegible] a citizen of the United States [illegible]

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That he verily believes that Letters Patent No. 1,879,863, granted to Hazeltine Corporation and referred to in the petition, specification and oath accompanying the aforesaid application and heretofore offered to be surrendered, are partly inoperative and invalid by reason of a defective and insufficient specification and claims and by reason of the patentee claiming as his own invention or discovery [illegible] a right to claim as new.

That said defect in the specification [illegible] in the omission in Figure 7 of a [illegible] lead of the first tube and of a connection [illegible] 73 to the end of the resistance [illegible] and in the presence of [illegible] 4, [illegible] and 7, and the [illegible] which as [illegible] 4, [illegible] subject-matter of [illegible] Nos. 1,87[illegible], [illegible] 5, [illegible] 1,879,863 to which [illegible] directed [illegible]

[illegible]

any fraudulent or deceptive intention on his part, namely, neither of the two defects corrected in Fig. 3 (the omission of the condenser and of the connection of the arrow 73 to the end of the resistance adjacent said arrow) was present in the corresponding Fig. 3 of his patent application filed July 7, 1927 (now pending), of which said original patent is a division, and the incorrect showing and omission in Fig. 3 of the divisional application was a draftsman's mistake or accident which was inadvertently overlooked and not corrected before the patent issued.

That the error of claiming more than the patentee had a right to claim and the defect and insufficiency residing in the inclusion in the specification and drawings of other forms of automatic amplification control and the lack of claims such as present claims 13-17 inclusive aforesaid arose as follows from inadvertence, accident or mistake and without any fraudulent or deceptive intention on his part, namely: that on January 3, 1926 he completed and successfully operated a radio receiver which included an amplifier of modulated-carrier signals and a system for automatically controlling the amplification thereof; that an application for patent was filed by the attorneys for Hazeltine Corporation July 7, 1927, Serial No. 203,879; that essentially and except for minor and unimportant differences the circuit arrangement used in said receiver for automatically controlling the amplification is illustrated in Figs. 1 and 2 of said original application filed July 7, 1927 (which are Figs. 1 and 3 of the present application for reissue) and specific circuit constants for said automatic amplification control circuit are given in said original application for original patent No. 1,879,863, p. 3, lines [illegible] inclusive, and present application for reissue,

p. 7, lines 16-19 inclusive); that said original application and patent No. 1,879,863 granted thereon also describes essentially except for minor unimportant differences the elements of said radio receiver with which said automatic amplification control was used and [illegible] describes the mode of operation of the specific amplification control system which was disclosed; that additionally said original application and the patent No. 1,879,863 describes among other things other circuits which [illegible] automatic amplification control; that [illegible] he was not versed in the construction of patent claims, the claims originally allowed (and subsequently issued in said patent No. 1,879,863) were brought to his attention by the attorneys for Hazeltine Corporation before the patent issued; that they then seemed to him to define and protect his automatic amplification control invention which had been embodied by him in said radio receivers; that [illegible] until Judge Galston so held that he became advised that certain of these claims did not define his invention and did not distinguish from what others had done and that said patent did not have sufficient and proper claims to protect his invention; that this opinion of Judge Galston was rendered August 6, 1934; that as promptly thereafter as possible a revision of the specification and claims of said patent was undertaken in order to correct the errors that had been made; that on September [illegible], 1934 the present application for reissue was made; that subsequently, namely on July 29, 1935, the Court of Appeals for the Second Circuit in an opinion by Judge Learned Hand affirmed said decision of Judge Galston; that the amendment to the specification and claims which are submitted herewith have been

made in the light also of said opinion of the Court of Appeals so as to assure that the claims in the reissue application accurately defined what he had invented and disclosed and had thought was protected by the original patent; that Exhibit A, pages 1-20 inclusive, submitted with the original oath in this application for reissue (when taken together with the amendments dated February 2, 1935 and May 2, 1935 and the amendment accompanying this oath) contains by reference to a printed copy of the original patent a true specification of the changes and corrections which it is desired to make in this reissue including the errors which it is claimed constituted the aforementioned inadvertence, accident or mistake.

David T. [illegible]

Subscribed and sworn to before me

this 31st day of August, 1935.

Notary Public

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71RE

IN THE UNITED STATES PATENT OFFICE

In re application of
HAROLD A. WHEELER
Serial No. 743,651
Filed September 26, 1934
Reissue of Patent No. 1,879,863
Div. 51 - Room [illegible]

FOR: "VOLUME CONTROL".

New York, N. Y. Sept. 16, 193[illegible].

SUPPLEMENTAL AMENDMENT.

Honorable Commissioner of Patents,
Washington, D. C.

S I R:

Supplementing [illegible]
September [illegible], [illegible]
amend the application as follows:

[illegible]
1[illegible], 11, [illegible], 17, [illegible]
same claims [illegible] as follows:

18 — 2. In a signal receiver having a carrier-frequency amplifier which includes at least one vacuum tube having a cathode and a control electrode, a two-electrode rectifier coupled to the output circuit of said amplifier, a high resistance connected between the rectifier anode and the amplifier cathode, means including said resistance for maintaining the average potential of said anode normally negative relative to at least part of said amplifier cathode and increasingly negative with increasing amplified signal output from said amplifier, and a direct-current connection from said anode back to said amplifier control electrode whereby the amplification of said amplifier is regulated automatically.

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2. In a carrier-current signaling system, in combination, a vacuum tube amplifier having a cathode and a control electrode, a vacuum tube detector coupled directly to the output of said amplifier, said detector having a cathode and an output electrode, means for maintaining said detector cathode at substantially the same potential as said amplifier cathode, means for maintaining said output electrode at a negative potential with respect to said cathodes, means causing said output electrode to become more negative in the presence of an amplified signal, and a direct-current connection between said output electrode and said control electrode.

3 3. A combination according to claim 2 in which the means for maintaining the detector output electrode at a negative potential with respect to said cathodes is a resistance connected between said output electrode and the detector cathode.

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9. In a modulated-carrier signal receiver having a carrier-frequency amplifier, a two-electrode rectifier coupled to the output circuit of said amplifier, which rectifier produces a modulated uni-directional voltage, a direct-current connection from said rectifier to an element of said amplifier whereby the amplification is regulated automatically, and a connection from said rectifier to a modulation-frequency amplifier whereby the signal is further amplified, said connection from said rectifier to said modulation-frequency amplifier including a condenser in series for preventing the uni-directional component from being impressed upon the input of said modulation-frequency amplifier.

10. In a signaling system, a vacuum tube amplifier having a cathode and a control electrode, a diode detector coupled to said amplifier, said detector having a cathode and an anode, means for maintaining said cathodes at substantially the same potential, means including a high resistance connected between the detector anode and cathode for maintaining said anode normally slightly negative relative to said cathodes, means for causing said anode to become more negative in the presence of an amplified signal, and a direct-current connection between said control electrode and said anode, whereby the amplification of said amplifier is regulated automatically.

25 11. In a modulated-carrier signal receiver having a carrier-frequency amplifier adapted to amplify modulated signals prior to detection, which amplifier has means for tuning to a desired signal and includes at least one amplifier vacuum tube having a cathode and a control electrode and possessing the property that its amplification decreases with increasingly negative biasing potential on said control electrode relative to the cathode, a system of automatic amplification control which includes a second vacuum tube coupled to the output circuit of the amplifier

B 713

by means no more selective than the amplifier, said second vacuum tube having an output electrode, means for maintaining the average potential of said output electrode normally slightly negative relative to at least part of said amplifier cathode and increasingly negative with increasing amplified signal output from said amplifier, a direct-current connection from said output electrode back to the amplifier control electrode for impressing thereon a negative biasing potential which varies in accordance with the average potential of said output electrode, whereby the carrier-frequency amplification in said amplifier is substantially decreased automatically with increasing amplified signal output from said amplifier, and a visual indicator coupled to the output circuit of the amplifier and responsive to the relative magnitude of said output, whereby the visual indication follows the strength of the detected signal and thereby facilitates tuning.

7.24 7. In a modulated-carrier signal receiver having a carrier-frequency amplifier adapted to amplify modulated signals prior to detection, which amplifier has means for tuning to a desired signal and includes at least one amplifier vacuum tube having a cathode and a control electrode and possessing the property that its amplification decreases with increasingly negative biasing potential on said control electrode relative to the cathode; a system of automatic amplification control which includes a two-electrode rectifier coupled to the output circuit of the amplifier by means no more selective than the amplifier, a high resistance connected between the rectifier anode and said amplifier cathode, means including said resistance for maintaining the average potential of said anode normally negative relative to

at least part of said amplifier cathode and increasingly negative with increasing amplified signal output from said amplifier, a direct-current connection from said anode back to said amplifier control electrode for impressing thereon a negative potential which varies in accordance with the average potential of said anode, whereby the carrier-frequency amplification in said amplifier is substantially decreased automatically with increasing amplified signal output from said amplifier, and a visual indicator coupled to the output circuit of the amplifier and responsive to the relative magnitude of said output, whereby the visual indication follows the strength of the detected signal and thereby facilitates tuning.

8. An arrangement according to claim 7 in which said visual indicator is connected in the anode circuit of said amplifier vacuum tube.

13. In a modulated-carrier signal receiver having a carrier-frequency amplifier adapted to amplify modulated signals prior to detection, which amplifier has means for tuning to a desired signal and includes at least one amplifier vacuum tube having a cathode and a control electrode and possessing the property that its amplification decreases with increasingly negative biasing potential on said control electrode relative to the cathode, a system of automatic amplification control which includes a second vacuum tube coupled to the output circuit of the amplifier by means no more selective than the amplifier, said second vacuum tube having an output electrode whose space current circuit includes resistance connected between said output electrode and said amplifier cathode, means including said resistance for maintaining the average potential of said output electrode normally negative relative to at least part of said amplifier cathode and increasingly negative with increasing amplified signal output from said ampli-

fier, a direct-current connection from said output electrode back to said amplifier control electrode for impressing thereon a negative biasing potential which varies in accordance with the average potential of said output electrode, a condenser connected between said amplifier cathode and a point on said direct-current connection, and resistance in said direct-current connection between said point and said output electrode which with said condenser provides a time constant predetermined to filter out voltage fluctuations at frequencies of signal modulation, whereby the carrier-frequency amplification in said amplifier is substantially decreased automatically with increasing amplified signal output from said amplifier and the detected signal strength is automatically controlled irrespective of whether the amplifier is exactly in tune with the signal carrier.

14. In a modulation-carrier signal receiver having a carrier-frequency amplifier adapted to amplify modulated signals prior to detection, which amplifier has means for tuning to a desired signal and includes at least one amplifier vacuum tube having a cathode and a control electrode and possessing the property that its amplification decreases with increasingly negative biasing potential on said control electrode relative to the cathode; a system of automatic amplification control which includes a two-electrode rectifier coupled to the output circuit of the amplifier by means no more selective than the amplifier, a high resistance connected between the rectifier anode and said amplifier cathode, means including said resistance for maintaining the average potential of said anode normally negative relative to at least part of said amplifier cathode and increasingly negative with increasing amplified signal output from said amplifier, a direct-current

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connection from said anode back to said amplifier control electrode for impressing thereon a negative biasing potential which varies in accordance with the average potential of said anode, a condenser connected between said amplifier cathode and a point on said direct-current connection, and resistance in said direct-current connection between said point and said anode which with said condenser provides a time constant predetermined to filter out voltage fluctuations at frequencies of signal modulation, whereby the carrier-frequency amplification in said amplifier is substantially decreased automatically with increasing amplified signal output from said amplifier and the detected signal strength is automatically controlled irrespective of whether the amplifier is exactly in tune with the signal carrier.

15. In a modulated-carrier signal receiver having a carrier-frequency amplifier which includes at least one amplifier vacuum tube having a cathode and a control electrode and possessing the property that its amplification decreases with increasingly negative biasing potential on said control electrode relative to the cathode; a system of automatic amplification control which includes a two-electrode rectifier coupled to the output circuit of the amplifier, a high resistance connected between the rectifier anode and said amplifier cathode, means including said resistance for maintaining the average potential of said anode normally negative relative to at least part of said amplifier cathode and increasingly negative with increasing amplified signal output from said amplifier, a direct-current connection from said anode back to said amplifier control electrode for impressing thereon a negative biasing potential which varies in accordance with the average potential of said anode, a condenser connected between said ampli-

fier cathode and a point on said direct-current connection, and resistance in said direct-current connection between said point and said anode which with said condenser provides a time constant predetermined to filter out voltage fluctuations at frequencies of signal modulation, whereby the carrier-frequency amplification in said amplifier is substantially decreased automatically with increasing amplified signal output from said amplifier.

18. In a modulated-carrier signal receiver having a carrier-frequency amplifier which includes at least one amplifier vacuum tube having a cathode and a control electrode and possessing the property that its amplification decreases with increasingly negative biasing potential on said control electrode relative to the cathode; a system of automatic amplification control which includes a two-electrode rectifier coupled to the output circuit of the amplifier, means for maintaining the amplifier and rectifier cathodes at substantially the same potential, a high-resistance connected between the anode and the cathode of the rectifier, means including said resistance for maintaining the average potential of said anode normally negative relative to at least part of said amplifier cathode and increasingly negative with increasing amplified signal output from said amplifier, a direct-current connection from said anode back to said amplifier control electrode for impressing thereon a negative biasing potential which varies in accordance with the average potential of said anode, a condenser connected between said amplifier cathode and a point on said direct-current connection, and resistance in said direct-current connection between said point and said anode which with said condenser provides a time

constant predetermined to filter out voltage fluctuations at frequencies of signal modulation, whereby the carrier-frequency amplification in said amplifier is substantially decreased automatically with increasing amplified signal output from said amplifier.

17. In a modulated-carrier signal receiver having a carrier-frequency amplifier which includes at least one amplifier vacuum tube having a cathode and a control electrode and possessing the property that its amplification decreases with increasingly negative biasing potential on said control electrode relative to the cathode, said receiver also having a modulation-frequency amplifier which is coupled to a signal reproducer; a system of automatic amplification control which includes a two-electrode rectifier coupled to the output circuit of the carrier-frequency amplifier, a high resistance connected between the rectifier anode and said amplifier cathode, means including said resistance for maintaining the average potential of said anode normally negative relative to at least part of said amplifier cathode and increasingly negative with increasing amplified signal output from said carrier-frequency amplifier, a direct-current connection from said anode back to said amplifier control electrode for impressing thereon a negative biasing potential which varies in accordance with the average potential of said anode, a condenser connected between said amplifier cathode and a point in said direct-current connection, resistance in said direct-current connection between said point and said anode which with said condenser provides a time constant predetermined to filter out voltage fluctuations at frequencies of signal modulation, whereby the carrier-frequency amplification is substantially decreased automatically with increasing amplified signal output from said carrier-frequency amplifier, and [illegible]n-

frequency connection from said anode to the modulation-frequency amplifier, whereby the rectifier serves also for signal detection, and manually adjustable means for determining the modulation-frequency amplification, whereby the reproduced signal is maintained substantially at any desired volume. (20)

The amendments directed by the Amendment filed on or about September 3, 1935, to be made to claims 4, 7, 8, 9, 11, 13, 14, 15, 16 and 17 may be disregarded if the same have not already been entered.

REMARKS

The claims as herewith presented are precisely the same as they were intended to be as the result of the amendment filed on or about September 3rd. They have been retyped in amended form at the suggestion of the Examiner at an oral interview, to decrease the possibility of error and to facilitate examination.

In rewriting the claims stenographic errors appearing in the amendments to claims 13 and 17 have been corrected as follows: On page 6 of the Amendment of September 3rd, where line 1 of claim 13 was amended, the word "a" should not have been cancelled. Referring to page 7 of the same amendment, the further instructions for amendment to claim 13 at lines 23, 24, 26 and 27 were intended to be with reference to lines 24, 25, 27 and 28, respectively. In page 12 of the amendment, the insert requested to be made at lines 6-8, inclusive, of claim 17 should have included the word "carrier-frequency" before "amplifier" in line 5 of the insert. In page 13 of the amendment, the insert after "modulation" in line 23 of claim 17, should have included the word "automatically", after "decreased" in the second line of the insert. Referring to claim 17, line 31 thereof was intended to be amended by the cancellation of the words "thereby" and "the".

After the foregoing corrections are made to the amendment of September 3rd, all of the claims herewith presented will correspond exactly to those as heretofore amended.

The claims as herewith presented are arranged in the order in which it is requested that they be printed in the issued patent, the original numbering having been retained for identification.

Respectfully submitted,

[illegible]

Attorneys for Applicant.

COMMISSIONER OF PATENTS [illegible]

SERIAL NO. [illegible]

DEPARTMENT OF COMMERCE

UNITED STATES PATENT OFFICE

WASHINGTON

Sir:

Your application for Reissue [illegible]

for improvement in [illegible]

has been examined and allowed.

The patent will be forwarded to you as soon as [illegible]

in due order of business.

Very respectfully,

~~Thomas E. Robertson~~

At this point was included a copy of Wheeler Reissue patent No. 19,744 which was omitted in printing. It is included herein at pages 867 to 874 as Plaintiff's Exhibit No. 1.

1934
1933

CONTENTS

...cation	... papers
[illegible]	Oct 1, 1934
... Report	Oct 1, 1934 — [illegible]
[illegible]	Nov 13, 1934
[illegible]	FEB 12 1935
...endment a	MAY 2 1935
Letter [illegible] Patent	MAY 2 1935
[illegible]	July 17, 1935
...endment B	Sept 3, 1935
...endment C	SEP 11 1935

DEFENDANT'S EXHIBIT B

[illegible]

DEPARTMENT OF COMMERCE

UNITED STATES PATENT OFFICE

To all persons to whom these presents shall come, Greeting:

THIS IS TO CERTIFY that the annexed is a true copy from the records of this office of the File Wrapper, Contents and Drawings, in the matter of the

Letters Patent of

Harold A. Wheeler, Assignor to
Hazeltine Corporation,

Number 1,879,863, Granted September 27, 1932,

for

Improvement in Volume Control.

IN TESTIMONY WHEREOF I have hereunto set my hand and caused the seal of the Patent Office to be affixed, at the City of Washington, this twenty-eighth day of June, in the year of our Lord one thousand nine hundred and thirty-four and of the Independence of the United States of America the one hundred and fifty-eighth.

ATTEST:

Chief of Division.

Commissioner of Patents.

NUMBER (Series of 1925)

1[illegible]386

DIV. 51

PATENT NO.

1930

DATED

(EX'R'S BOOK)

Name [illegible]

of ~~[illegible]~~

State of [illegible]

Invention [illegible]

VOLU[illegible]

ORIGINAL

RENEWED

APPLICATION FILED COMPLETE

PARTS OF APPLICATION FILED

Petition, Specification,

Oath, First Fee $[illegible]

4 *sheets Drawings*

Examined and passed for Issue [illegible]

Notice of Allowance [illegible]

Final Fee [illegible]

Attorney [illegible]

Associate Attorney [illegible]

No. of Claims Allowed [illegible]

Title as Allowed [illegible]

13

PENNIE, DAVIS, MARVIN AND EDMONDS

COUNSELLORS AT LAW

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NOV 13 30

C 3871
YY

November 11th, 1930

Honorable Commissioner of Patents,

Washington, D. C.

S i r :

We enclose herewith an application of Harold A. Wheeler for improvements in "Volume Control". This application is a division of application Serial No.203,879 now on file in the Patent Office.

The application papers comprise a petition, specification, oath and four sheets of drawings and were executed on November 6th, 1930.

We are enclosing our check for twenty-five dollars ($25.00) to cover the filing fee.

Yours very truly,

Pennie Davis Marvin and Edmonds

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PETITION

[illegible]3-71
(64-

TO THE COMMISSIONER OF PATENTS:

Your petitioner, HAROLD [illegible],

a citizen of [illegible],

residing at

in the County [illegible], State of New York,

whose Post-Office address is [illegible] Street,
[illegible] Heights,
New York, N. Y.

prays that Letters Patent may be granted to him for improvements in

VOLUME CONTROL

as set forth in the annexed specification.

And he hereby appoints William H. Davis, Arba B. Marvin, Dean S. Edmonds, Frank E. Barrows, W. Brown Morton, Merton W. Sage, Willis H. Taylor, Jr., Ernest H. Merchant, George E. Middleton, Morris D. Jackson, R. Morton Adams, Raymond F. Adams and Leslie B. Young (constituting the firm of Pennie, Davis, Marvin & Edmonds, 165 Broadway, New York City, Registration No. 10839) and each of them, his Attorneys, with full power of substitution and revocation, to prosecute this application, to make alterations and amendments therein, to sign the drawings, to receive the Patent, and to transact all business in the Patent Office connected therewith.

(Inventor's Full Name)

SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN, that I, [illegible],

residing at Jackson Heights,

in the County of Queens, State of [illegible],

have invented certain new and useful improvements in

VOLUME CONTROL

and I do hereby declare the following to be a full, clear and exact description of the invention, such as will enable others skilled in the art to which it appertains, to make and use the same:

[illegible]-3871
64-U

This invention relates to amplifiers, [illegible] particularly to [illegible] current signaling system [illegible] is automatically maintained [illegible] level.

This application [illegible] Serial No. 2[illegible], filed [illegible].

When amplifiers are employed [illegible] signal voltage it [illegible] control automatically the amplitude [illegible] voltage. To this end the present invention [illegible] for effecting automatic amplification [illegible] arrangement, for example, [illegible] radio receivers such as are employed [illegible] signals, because it prevents [illegible] amplifier stage of the receiver, [illegible] result in distortion of the [illegible], as [illegible] loud and harsh reproduction.

Another advantage [illegible] of the amplified [illegible] current signal [illegible] distant or a high-power station, [illegible] since it has been found [illegible] that when the receiver was [illegible] by, or a high-power station, [illegible] was very loud, whereas [illegible] distant, or a low-power station, it was relatively weak, with the result that if [illegible] from both near and distant stations, and from high-power and low-power stations, it [illegible] volume controlling means in the receiver to compensate for these unequal signals.

It has also been a common experience in the use of former radio receivers that the reproduced signal was not uniform due to the phenomenon of "fading", whereby the received signal occasionally, or periodically, became much weaker, or faded almost to the point of inaudibility. Since the present invention provides an amplifier which automatically compensates for inequalities in the received carrier-current signal strength, when "fading" takes place the degree of amplification is correspondingly increased and the reproduced signal maintained at its former volume, so that a listener is unaware that variation of the received carrier-current signal is occurring. This automatic compensation for signal fading is especially advantageous in commercial radio telephony and like systems.

In existing radio receivers in which operating current is derived from the municipal power system, it has been found that when there is considerable variation in the line voltage supply, the volume of the reproduced signal is not uniform. An additional advantage of the present invention is that of automatically compensating for such line voltage variations with the result that the reproduced signal is uniform in volume.

A still further advantage is the saving in plate current which is automatibally effected during the reception of powerful signals, for the reason that this invention incidentally provides means for reducing the plate current of one or more amplifying tubes as the signal strength increases.

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Fig. 1 is a circuit diagram of a [illegible] radio receiver which includes the [illegible] consisting of a three-stage radio-frequency amplifier, followed by a rectifier, a two-stage audio-frequency [illegible] loud speaker, or other [illegible] device.

Fig. 2 shows [illegible] the radio-frequency antenna voltage [illegible] amplified voltage, with and without the application of the present invention.

Fig. 3 shows a circuit diagram of [illegible] embodiment of the invention in which there [illegible] stage tuned radio-frequency amplifier, a [illegible] three-stage audio-frequency amplifier.

Fig. 4 [illegible] a radio receiver [illegible] amplifier, a detector and a two-stage audio-frequency amplifier.

Fig. 5 shows a modified form of [illegible] ment and controlling battery which [illegible] the corresponding elements in [illegible].

Fig. 6 shows a [illegible] receiver for operating the [illegible] entirely from a rectifier [illegible] of current, thus eliminating [illegible] now so widely used.

Fig. 7 is a [illegible] in which a [illegible] combined [illegible].

Fig. 3 shows graphically a comparison between the performance of the two-electrode valve or rectifier, and of the three-electrode detector.

Referring in detail to Fig. 1, there is shown an antenna 1 connected to ground 2 through the primary winding 3 of a radio-frequency transformer, the secondary winding 5 of which, tuned by a variable condenser 6, is connected at one point to the filament of the vacuum tube 7 in the first radio-frequency amplifying stage and at another point to the grid 11 of this vacuum tube. The output circuit of this vacuum tube extends from the filament system, through a high-voltage battery "B", a milliammeter 12, primary winding 13 of a second radio-frequency transformer to the anode or plate 14 of this vacuum tube. In order to neutralize the inherent capacity between the grid 11 and the plate 14, and thereby to prevent oscillations, and otherwise to increase the effectiveness of the present invention as hereinafter described, a neutralizing winding 15, electromagnetically coupled to winding 13, and a neutralizing condenser 3 are employed in the manner described in the U.S. Patents to Hazeltine Nos. 1,489,228 and 1,533,858.

The second stage of radio-frequency amplification including the vacuum tube 18 neutralized by cooperation of coil 19 and condenser 4, like the first stage, comprises the secondary winding 16 of the last-mentioned radio-frequency transformer tuned by a variable condenser 17 connected between the filament system of the vacuum tube 18 and the grid thereof. The output circuit of this vacuum tube also includes the high-voltage battery "B" and a primary winding 20 of a second radio-frequency transformer, while the secondary winding 21 of this transformer tuned by a variable

condenser 22 is included in the input circuit of a third stage of radio-frequency amplification which includes vacuum tube 23. The inherent capacity effective between the electrodes 24 and 25 is neutralized by a network including the neutralizing condenser 28 and the neutralizing winding 29 as described in the mentioned patents. The output circuit of the vacuum tube 23 includes the primary winding 30 of a third radio-frequency transformer and the high-voltage battery "B". The secondary winding 31 of this last-mentioned transformer, tuned by a variable condenser 32, is connected in the input circuit of a rectifier 33 which input circuit includes the fixed condenser 2, the rectifier employed may be of the type commonly known in the art as a two-electrode "Fleming" valve, or may consist of an equivalent such as a three-electrode vacuum tube, as shown, having its grid 12 and its plate or anode 35 directly connected together to comprise in effect a single anode.

It may here be noted that throughout the present specification and claims the terms "rectifier" and "detector" are, in general, used interchangeably, the terms "rectifying" and "converting" being employed in the general sense to include the process of changing alternating current into a form of direct current or modulated unidirectional current. Likewise, the terms "carrier-current" and modulation current" may be substituted, respectively, for "radio-frequency current" and "audio-frequency current", since the description herein of radio-frequency amplifiers and audio-frequency amplifiers is merely by way of example of a typical embodiment of the present invention.

In the absence of the present invention including the control circuit 36, to be described, the three-stage amplifier functions in a manner well-known in the art to amplify the incoming signal intercepted on the antenna 5. The output circuit of the rectifier 33 includes what may be termed a "rejector" circuit for stopping radio-frequency currents which have passed through the rectifier, and consists of a network including a resistance 34 and a by-pass condenser 37 connected between the anode 35 and the filament 38 of the rectifier. The output circuit of the rectifier is coupled to the input circuit of an audio-frequency amplifying vacuum tube 39 through an audio-frequency-pass filter including a fixed condenser 40 and an impedance 41 connected between the filament 42 and the grid 43 of this vacuum tube. The output circuit of this amplifier is connected between the filament 42 and plate 44 through the high-voltage battery "B" and the primary winding 45 of an audio-frequency transformer, the secondary winding 46 of which is connected in the input circuit of a second audio-frequency tube 47, while a resistance 48 connected across the winding 46 serves to give the audio amplifier substantially uniform amplification over the desired frequency range. Instead of employing resistance 48, a closed copper band of suitable size may be placed around the transformer winding so as to be electromagnetically coupled thereto. A loud speaker or other reproducing device 50, or if required, a coupling device for a telephone system, is connected in the output circuit of the last audio-frequency amplifying tube 47. It is presumed that adequate precautions against undesired electromagnetic coupling between the various radio-frequency coupling transformers are included in all of the arrangements herein disclosed.

In accordance with the main feature of the present invention, means are provided to control automatically the degree of amplification effected in the radio-frequency amplifying stages. These means include a reistance 51, connected between the filament 38 and the anode 35 of the rectifier, through which the pulsating rectified or converted current flows, thereby developing a negative voltage at terminal 52. This negative voltage is applied over conductor 36 through the impedance 53 and the secondary winding 7 of the first radio-frequency transformer to grid 11 of the first radio-frequency stage. Impedance 53, together with blocking condenser 54, is effective to filter out and reject any audio-frequency currents which otherwise might be present in the conductor 36.

To complete the description of the system illustrated in Fig. 1 certain design data or constants are given herewith. It should be understood, however, that these, as well as all other constants appearing in the present specification, are mentioned merely by way of example in describing certain specific embodiments which in practice have proved eminently satisfactory, and are not intended to suggest any specific limitations as to the scope of this invention. Accordingly, fixed condenser 2 may be of 0.0005 microfarads; 37 of 0.0001 microfarads; 54 of 0.01 microfarads; 40 of 0.005 microfarads; resistance 51 of 1 megohm; 34 of 1 megohm; and 41 and 53 of 2 megohms each.

In the operation of the receiver shown in Fig. 1 a signal intercepted on the antenna 5 is successively amplified through the neutralized radio-frequency stages indicated by the vacuum tubes 9, 15 and 23. This amplified

signal voltage is then rectified by the rectifier 33, and the rectified pulsating current is successively amplified by the audio amplifying stages including vacuum tubes 39 and 47, after which it may be reproduced as sound by the loud speaker 50. When the rectified or converted signal current flowing through the resistance 51 is greater than a predetermined value, there is developed at the terminal 52 sufficient negative biasing voltage which in turn is impressed, through the conductor 36, upon the grid 11 of the vacuum tube 9, to reduce the amplification of this tube. It will be apparent that as the magnitude of the rectified current flowing through resistance 51 decreases with weaker signals, the voltage at terminal 52 becomes less negative, and the negative biasing voltage impressed upon the grid 11 also diminishes so that the vacuum tube 9 effects an increased degree of amplification. In this manner, the radio-frequency voltage applied to the input of the rectifier is maintained at a nearly constant predetermined value, and the volume of the reproduced signal is substantially uniform under all conditions. The degree of volume of the reproduced signal is then determined by adjustment of rheostat 49 which controls the heating current in the filament 42 of the first audio-frequency amplifying tube 39. The neutralization of the grid-plate capacity of the radio-frequency amplifying tubes is, in combination with the present invention, particularly valuable in that it allows an increase in the effectiveness of the amplification control, because such neutralization prevents radio-frequency energy from passing through the grid-plate capacity of the tubes. Thus the relay action of the tubes is almost entirely subject to the control by grid bias voltage provided in accordance with this invention.

The time required for operation of the control system would ordinarily be determined by the lowest audio-frequency modulation which must be reproduced. Fading, for example, might be considered a form of modulation; the frequency of the rise and fall of signals due to fading being the frequency of modulation. If this frequency of modulation be increased sufficiently, the effect will be audio-frequency modulation. It will thus be seen that if the automatic control attained by the present invention be allowed to respond too quickly, it will tend to smooth out the desired modulation of the signals at the lower audio frequencies. Hence, a time constant of operation is chosen which will be greater than the period of the audio frequencies which the system is intended to amplify. This time constant of the control circuit is equal to the product of the series resistance and the shunt capacitance of the grid bias circuit, represented in Fig. 1 by resistance 53 and capacitance 54. However, since the time constant can always be reduced to a value equal to the period of the lowest modulation frequency, it may readily be set to meet the requirements of nearly any special case which may arise. For example, a value of two million ohms resistance and of 0.1 microfarad capacitance gives a time constant of one-fifth of a second, which does not appreciably affect the modulation of frequencies above five cycles. While this constant is greater than required from the point of view of satisfactory audio-frequency quality in the reproduction of music, there appears to be no need for more rapid control under the conditions usually encountered. The use in this connection of condensers of large capacitance, such as one-tenth microfarad,

likewise introduces another convenience in that the condensers may also serve to by-pass radio frequencies in order to prevent undesired coupling between the detector circuit and the first radio-frequency amplifying tube because of some impedances common to those two portions of the apparatus.

For a better understanding of the present invention reference is made to Fig. 2 from which it will be appreciated that in a system similar to that illustrated in Fig. 1, but in which no means for automatically limiting the degree of amplification is included, the amplified radio-frequency voltage is proportional to the radio-frequency antenna voltage, as indicated by curve 102. When, however, the present invention is employed in such an amplifier, the relation between the radio-frequency antenna voltage and the amplified radio-frequency voltage is indicated by curve 103 from which it will be seen that when at least a certain predetermined radio-frequency antenna voltage is present, (herein referred to as the "threshold antenna voltage") the amplified radio-frequency voltage approaches - but is always less than - another certain predetermined voltage value (herein referred to as the "cut-off voltage").

The modification illustrated in Fig. 3 is an especially desirable form of the present invention, and includes antenna 56, connected by means of a transformer 57 to a neutralized three stage tuned radio-frequency cascade amplifier including the vacuum tubes 58, 60 and 62 coupled by transformers 59 and 61. The last stage of the amplifier is connected by a transformer 63 to a two-electrode rectifier 64 of the type already described, the output circuit of which, including the resistance 65, is connected between the anode

66 and filament 67 of the rectifier, as previously explained. Resistance 72 and condenser 68 associated with this output circuit, constitute a "rejector" network which filters out the radio-frequency current component in the output circuit of the rectifier 64, while the network including condenser 69 and resistance 70 constitutes an audio-frequency-pass filter for coupling the output circuit of the rectifier to the input circuit of the audio-frequency amplifier which includes vacuum tube 71. Rheostat 73 controls the heating current supplied to the filament 74 of this vacuum tube, and thereby permits a manual adjustment of the volume of the reproduced signal desired by the listener. Audio-frequency transformer 76, which is preferably of a low ratio of transformation, couples the output circuit of vacuum tube 71 to a second audio-frequency amplifying tube 77. This last vacuum tube in turn is coupled by a second audio-frequency transformer 78 to a third audio-frequency amplifying tube 79 in the output circuit of which there is included a loud speaker 80.

In this arrangement automatic amplification control is effected in a manner slightly different from that shown in the diagram of Fig. 1, since in this instance the radio-frequency voltage of the signals intercepted by the antenna 56 is successively amplified by three neutralized tuned radio-frequency amplifying stages including the vacuum tubes 58, 60 and 62, of which two are controlled in accordance with the present invention. The amplified radio-frequency current is rectified by the rectifying valve 64, and successively amplified at audio-frequency by the vacuum tubes 71, 77 and 79. The rectified current in the output circuit of

the rectifier flows through the resistance 65, and thereby develops a negative voltage at the terminal 81, which voltage is applied through the impedances 72, 82, 83 and 85 to the grids 84 and 86 of the radio-frequency amplifying tubes 58 and 60. By thus simultaneously controlling the degree of amplification of two successive radio-frequency amplifying stages a greatly increased uniformity of regulation is attained. Impedance 82 and the condenser 87 constitute an audio-frequency-stop filter, so that substantially only direct-voltage is impressed upon the grids 84 and 86. It will be understood that the voltage developed at terminal 81 is a function of the amplified radio-frequency voltage delivered to the input circuit of the rectifier by the radio-frequency amplifying tubes 58, 60 and 62, and therefore, as the negative voltage at terminal 81 tends to increase with the increased signal, the resulting increase of biasing voltage impressed upon the grids of the tubes 58 and 60 limits the degree of amplification effected in the radio-frequency stages including those tubes.

In this arrangement the constants for the various resistances and condensers may, for example, be the same as those for the corresponding elements in Fig. 1. In addition the grid resistances 83 and 85 may have a value of 2 megohms each; and the grid condensers connected at the junction of these resistances and the grid electrodes 84 and 86 may each be of 0.001 microfarad capacity.

The modification shown in Fig. 4 differs from the arrangement of Figs. 1 and 3 mainly in that it employs a three-electrode vacuum tube which functions in the manner of the well-known three-electrode detector, and also effects

rectification, or conversion, of the radio-frequency carrier current to control amplification in the first radio-frequency stage of the receiver. As in the preceding arrangements, there is here employed an antenna or other suitable signal interceptor 88 coupled by means of a radio-frequency transformer 89 to a two-stage neutralized tuned radio-frequency amplifier including the vacuum tubes 90 and 91 coupled by means of a radio-frequency transformer 92. The output circuit of the last stage of the amplifier is connected by means of radio-frequency transformer 93 to the tuned input circuit of a three-electrode vacuum tube detector 94, which input circuit is tuned by the inductance of the secondary winding of transform[illegible] in shunt to variable condenser 95. A suitable negative voltage is maintained on the grid 96 of the detector tube, through the secondary winding of transformer 93, by "C" battery 97 and by potentiometer 98 connected across the filament of the detector tube. By means of this potentiometer connection, a negative voltage may be applied to the grid 96 varying from one volt to a maximum of five volts; the minimum value being the difference between the six volts of "C" battery 97 and the voltage drop across the filament of the detector. The output circuit of the detector includes the primary winding of transformer 99, a 45-volt battery 100 and a 500,000 ohm resistor 101, connected in series between the anode of the detector and the common "B" battery. A fixed condenser 104 by-passes the radio-frequency current that has passed through the detector, while the audio-frequency component of the rectified, or converted, current is transferred through the audio-frequency transformer 99 to the

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input circuit of an audio-frequency amplifying vacuum tube 105, the filament circuit of which includes rheostat 106 for controlling the arbitrary volume level of the amplified signals. The output circuit of the audio-frequency amplifier 105 is coupled by means of an audio-frequency transformer 107 to the input circuit of a second audio-frequency amplifying tube 108. The output circuit of this vacuum tube includes the usual loud speaker or indicating device 109. A resistance 110 is connected across the secondary winding of transformer 107 to secure substantially constant amplification within the frequency range of the audio-frequency amplifier, especially when the plate resistance of the preceding tube 105 is high as a result of the adjustment of rheostat 106.

For controlling the amplitude of the radio-frequency voltage applied to the input circuit of detector 94, a conductor 111 is connected at point 112 common to a terminal of resistor 101 and battery 100, and thence through the secondary winding of transformer 89 to the grid of the first radio-frequency amplifying tube 90. A by-pass condenser 113 connecting the conductor 111 to the filament system serves to filter out and reject any audio-frequency currents present in the circuit including the conductor 111, thereby insuring that these currents have no effect on the grid of the vacuum tube 90. Battery 100 is the source of negative biasing voltage applied to the control grid, or control-electrode, of the radio-frequency amplifying tube, this battery being so connected to the output circuit of the detector, or rectifier, that fluctuations of voltage in the detector output circuit cause equal fluctuations in the negative biasing voltage impressed upon the control-grid.

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In this embodiment, condensers 104 and 113 may be of 0.0005 microfarad and 1 microfarad capacity, respectively, while resistance 101 may have a value of 0.5 megohm.

In adjusting the receiver of Fig. 4, it is necessary to determine the correct setting of the detector grid potentiometer 98. This adjustment should be made while there is no signal being received, as follows: First, the switch 115 is closed, and the normal plate current of the tube 90 is noted on milliammeter 116. Then the switch is opened, thus placing the control circuit in operation. In general, the plate current of vacuum tube 90 will change when the switch is opened, since the grid voltage of this tube is dependent upon the control circuit. By varying the grid voltage of the detector by potentiometer 98, the plate current of tube 90 is then adjusted to the normal value, and the apparatus is ready for operation. Upon receipt of an amplified signal at the detector, the effect of the control circuit is to decrease the plate current through milliammeter 116, thereby reducing the amplification of the tube 90. When the receiver is tuned to the signal frequency, a minimum amplification is required, so that when the condition of resonance is attained the plate current of tube 90 is at a minimum value.

It is believed unnecessary to explain the operation of the two radio-frequency amplification stages, of the detector, or of the two audio-frequency amplification stages, for in operation they are substantially similar to those of the now well-known type of radio receiver employing neutralized two-stage radio-frequency and two-stage audio-frequency amplifiers. The control circuit operates, in the arrangement of Fig. 4, substantially in the same manner as

in Figs. 1 and 3, to apply a negative biasing voltage to the grid of the radio-frequency amplifying vacuum tube 90, this voltage being a function of the radio-frequency voltage which has been amplified by the vacuum tubes 90 and 91 and then applied to the input circuit of detector 94. Since the voltage applied over conductor 111 is a function of the amplified radio-frequency voltage, there is a maximum, or cut-off, detector voltage determined by the constants of the circuit, as shown in Fig. 2, beyond which the radio-frequency amplifier is prevented from effecting further amplification. This arrangement maintains the finally-amplified radio-frequency voltage at substantially constant value.

Fig. 5 shows an alternative system for coupling the detector to the first audio-frequency amplifying tube of Fig. 4. The coupling arrangement of Fig. 5 included within the dotted rectangle, when substituted for the corresponding portion enclosed within the rectangle of Fig. 4, provides a modified form of the invention. Corresponding elements of these two figures are identified by the same reference characters, from which it will be seen that Fig. 5 differs from Fig. 4 in that the transformer coupling between the detector 94 and the first audio-frequency amplifying tube 105 has been replaced by an impedance coupling arrangement including the condenser 117 and the impedance 118.

While this modification does not utilize a transformer having a step-up ratio such as is included in the arrangement of the former figure, it, nevertheless, introduces the advantage of effecting a more nearly constant degree of amplification at audio frequencies. When the modification of Fig. 5 is substituted in the system of Fig. 4,

as described, the values of elements 104 and 101 may be the same as mentioned above; the resistance connected in lead 111 may be of 2 [illegible]; 116 of 2 [illegible]; 117 of .005 microfarad; and 113 of [illegible].

Referring to Fig. 6, there is shown a [illegible] receiver of the unneutralized type in which the so-called "A", "B" and "C" batteries have been replaced by a source of rectified and filtered alternating current. In this embodiment of the invention there are provided three stages of tuned radio-frequency amplification in which the vacuum tubes of the successive stages are designated 119, 120 and 121, respectively. These several stages are transformer-coupled; and the last stage of the amplifier is coupled to a three-electrode vacuum tube detector 122, the grid bias voltage of which is controlled by potentiometer 128. In the output circuit of detector 122, there is provided a "rejector" circuit, similar to that previously described, for filtering out radio-frequency currents that have passed through the detector; and also an audio-frequency network, or impedance coupling, including condenser 123 and impedance 124, for passing the audio-frequency component of the rectified signal to the first audio-frequency amplifying vacuum tube 125. The filament of this tube is shunted by rheostat 129 which functions as a manual volume control. This last tube is transformer-coupled to a second stage of audio-frequency amplification, including the vacuum tube 126, in the output circuit of which there is provided a loud speaker, or other [illegible] indicating device, 127, which on [illegible] may be replaced by a [illegible] device in a telephone system. The filaments of these six vacuum tubes are

connected in series across a suitable resistance in the rectified, filtered source of power supply, giving a potential difference of 30 volts, thus taking the place of an "A" battery. The necessary "C", or bias, voltage is derived from a potential difference across a resistance in that portion of the power supply indicated by the reference character "C", while the plate-current supply is similarly derived from a resistance in that portion of the power supply indicated by the reference letter "B". It should be noted that the filament of the first radio-frequency amplifying tube 119 is connected to the positive terminal of the 30-volt "A" section of the power source, and that the filament of the detector tube 122 is connected to the negative terminal of this section. The constants of the elements of this embodiment may in general be similar to those suggested with reference to Fig. 5.

In adjusting the receiver of Fig. 6, the potentiometer 128 is adjusted with switch 115 open, as described in connection with the adjustment of the receiver of Fig. 4. This arrangement with the vacuum tube filaments connected in series obviates the necessity of a separate battery corresponding to 100 of Figs. 4 and 5, since the plate of the detector tube 122 can be positive relative to the filament of that tube, and at the same time maintains the grid of the first radio-frequency amplifying tube 119 negative relative to the filament of the same tube, due to the difference of potential between the two filaments. Thus the biasing voltage applied to the control-grid is derived from the voltage across the filaments instead of from a battery as in Figs. 4 and 5.

In Figs. 4 and 5, batteries "B" and 100 are connected in series in the plate circuit of detector 94 and both contribute to the detector plate current. The "B" battery supplies the voltage drop in resistor 101, while battery 100 supplies the plate voltage of detector 94. The presence in the detector plate circuit of the "B" battery, which is directly connected to the grounded filament circuit, in addition to auxiliary battery 100, allows the use of a high impedance 101 in the detector plate circuit with a resulting high sensitivity of the detector circuit. The same result is achieved in the arrangement of Fig. 6 by the cooperation of the "A" and "B" voltages in the detector plate circuit, as described before. In the event that tubes having an indirectly heated cathode are used instead of those having an incandescent filament cathode as represented in the figure, the same advantages may be obtained as pointed out in connection with Fig. 6, if the detector cathode is maintained at a potential much more negative than the cathode of the controlled tube or tubes, which, in the figure, is the first radio-frequency amplifier tube.

The circuit arrangement shown in Fig. 7 incorporates several advantages introduced by the present invention, some of which have been individually described above. Briefly, this arrangement [illegible] a combination of the features illustrated in and described in connection with Fig. 3 and Fig. 6. The reference [illegible] numbers [illegible] those of Fig. 6 and have the same significance. It will be noted in addition to the apparatus represented in Fig. 6 [illegible] is here illustrated a power source of [illegible] filtered alternating current which replaces the so-called "A" and "B" batteries represented in Fig. [illegible] and in addition [illegible] a source of "C" [illegible]

or grid bias voltage for tube 79. The grid of tube 77 is biased by connecting the "grid return lead" to an appropriate point in the series filament circuit, as shown. The power source is similar to that shown in and described in connection with Fig. 6. The present arrangement thus includes the advantages of neutralized radio-frequency amplifying stages, automatic volume control applied to the first two stages of the radio-frequency amplifier, a two-electrode valve, or rectifier, and the complete elimination of all batteries for supplying operating potentials to the system. As is also true of the arrangement of Fig. 6, the automatic volume control not only compensates for fluctuations in the strength of the incoming signals, but also compensates for reasonable variations in line voltage of the alternating current power supply.

As in Fig. 6 the variable tuning condensers C_1-C_4 are grounded in order to eliminate undesirable capacity effects as well as to make it practicable to connect the condensers on a single shaft for uni-control, if desired. As in Fig. 6, it will be seen that the power supply of Fig. 7 is not grounded, thus eliminating the danger of short-circuiting the direct current supply when a separate ground is necessary for the alternating-current rectifying and filtering system. In certain instances, Figs. 6 and 7 differ in the connection of certain by-pass condensers. The purposes and reasons for the positions of these by-pass condensers should be apparent to those skilled in the art.

Assuming that the vacuum tubes employed are of the type having five-volt filaments, 35 volts of filament, or "A", supply is needed. As above mentioned, the automatic volume control is here applied to two tubes, namely 58 and 60; the cut-off being effected with the use of two different plate, or "B", voltages. The plate electrode 66 of rectifier 64 is more negative relative to the filament of tube 58 than relative to the filament of tube 60, by the 5-volt drop across one filament. To compensate for this difference, 35 volts higher "B" voltage is applied to the plate of tube 58 than to the plate of tube 60, which makes both tubes cut off practically at the same time. The reason for applying a "B" voltage of 85 volts (which, of course, is to be added to the 35 volts "A" voltage, to the plate of tube 60, whereas a "B" voltage of 90 volts is applied to the plates of the radio-frequency amplifying tubes of Fig. 6, is that the arrangement of Fig. 7 employs one more tube than Fig. 6; the difference of 5 volts being included in the "A" supply, as will be seen by comparing the two figures. Thus, actually, the plates of the radio-frequency amplifying tubes 119, 120 and 121 of Fig. 6 are provided with 90, 95 and 100 volts, respectively. Similarly the plates of the amplifying tubes of Fig. 7 are supplied with 85 to 155 volts.

In addition to the combined advantages just outlined, the arrangement of Fig. 7 also includes an additional feature which has not previously been described namely, the means 135 for determining the filament current supplied to one of the amplifying tubes. As has been explained in connection with Fig. 6, when operating the

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filaments of the several vacuum tubes on rectified and filtered current from an alternating current power source, it is desirable that the filaments be connected in series since it is at present more practicable to provide a current supply at a comparatively high voltage and low current. Fig. 6 shows a shunt rheostat 129 connected in parallel with the filament of tube 125 so that the current divides between the rheostat and the filament. While this means for controlling the filament emission of a single tube, as shown in Fig. 6, is fairly satisfactory, the arrangement shown in Fig. 7 is a substantial improvement. With the former method an increase in current through the controlled filament is accompanied by a smaller increase in current through the other filaments in series. The improved arrangement shown in Fig. 7, on the other hand, by providing three resistances, two of which are simultaneously variable, allows a variation of the voltage on one or more filaments without affecting the current through the other filaments; or, more generally, without changing the load on the filament-current supply. It is apparent that the benefits of this device will be especially manifest in an arrangement such as the present, wherein the current supply for the filaments is obtained from a rectified, filtered alternating current source, particularly when the rectifying device is of the common type without automatic voltage regulation. The compound rheostat 130 comprising resistances R_1 and R_2 is so arranged that a movement of the control knob will increase the one resistance, while diminishing the other in proportion. One of these resistances, namely R_1 is connected in series with resistance R_0 in shunt with filament 74 of tube 71, the resistance of filament 74 being represented by "R_f".

It may here be pointed out that while Fig. 7 illustrates the manual control of the filament of only one tube, namely 74, the filaments of other tubes could be connected either in series or parallel with filament 74 if it were desired that independent simultaneous control be had of more than one filament. "R_f" may, therefore, be taken to represent the effective resistance of the filaments to be controlled. When the two resistances R_1 and R_2 and the fixed resistance R_0 are properly proportioned to the normal operating resistance R_f of the filament or filaments of the tubes to be controlled, the resistance of the system as a whole will remain substantially constant during adjustment of the control device 130. By way of illustration, the following data are given for Fig. 7, assuming the tubes to be all of the well-known 201A type, each filament being of 20 ohms resistance: R_f will equal 20 ohms; R_0 may equal R_f; R_1 may equal $8R_f$; and R_2 may equal $\frac{1}{2}R_f$. Accordingly, to control one tube when R_f equals 20 ohms, R_0 will equal 20 ohms, R_1 will equal 160 ohms, and R_2, 10 ohms.

It is believed unnecessary to describe the method of controlling the signal amplification in the arrangements of Figs. 5, 6 and 7 since they are substantially similar in operation to that of the systems described in reference to Figs. 1, 3 and 4. It should be mentioned, however, that the advantages of the present invention are especially apparent in systems such as shown in Figs 6 and 7, because of the fact that any reasonable fluctuations in the voltage of the power supply line are thus automatically compensated for, and uniform volume of signals is assured.

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There are advantages attending the use, in connection with the present invention, of the two-electrode rectifier circuit typified by Figs. 1, 3 and 7, which may not be apparent from the foregoing discussion. It is impossible to overload this type of rectifier, and the rectified output voltage is directly proportional to the applied alternating signal voltage when this voltage is large, say over two volts. The control system in the circuits of the figures referred to requires a large operating voltage, say ten volts, so that the latter condition of large signal voltage is realized. No such simple relationship is possible in a three-electrode detector, whose rectified output never exceeds a limiting upper value, and is never proportional to the applied voltage, except over a very small range of voltages. This distinction will be seen from Fig. 8 where the abscissae "A.C." represent the alternating signal voltages, whereas the ordinates "D.C." represent the rectified output voltages. It is well known that the linear curve is much more desirable when minimum distortion of a modulated signal is desired, and it will be observed from Fig. 8 that the preferred type of curve is obtained from the two-electrode rectifier.

Insert A'

The three-electrode detector is useful for relatively small applied voltages, and the rectified output voltage is then approximately proportional to the square of the applied voltage, i.e., to the power associated with the applied voltage. For this reason the rectified voltage increases with the carrier wave modulation. When such a detector is used in the control system, as in Figs. 4, 5 and 6, the total power from the radio-frequency amplifier is

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maintained at a substantially constant level, the amplitude of the carrier wave being decreased in the presence of modulation. It is desirable to maintain the carrier wave at a constant amplitude at the output of the amplifier, and this is accomplished by the two-electrode rectifier as shown in Figs. 1, 3 and 7. The control system maintains constant the average signal amplitude which is equal to the carrier wave amplitude and independent of the degree of modulation.

It will be observed that in a system employing a two-electrode rectifier such as represented by valve 33 of Fig. 1, and 64 of Figs. 3 and 7, the control bias voltage is independent of the "B" or anode battery voltage. Since the rectifier is not an amplifier, is not critical, and requires neither anode nor biasing battery, no adjusting devices are required. This is not the case in the three-electrode detector circuits, so that a potentiometer, 98 or 128 in Figs. 4 or 6, respectively, must be adjusted as described to accommodate the control bias to any particular combination of tubes and "B" voltage. On the other hand, the latter type of detector is more sensitive because it is also an amplifier, so that the control system operates on a smaller applied alternating voltage.

In the foregoing description, tuned radio-frequency receivers of the neutralized and unneutralized types have been referred to. It should be pointed out, however, that the present invention may be employed with equal effectiveness to any radio receivers in wired radio and space radio systems, and that it has been found especially applicable to receivers of the super-heterodyne type. For this reason the present disclosure of typical embodiments of the

invention should not be construed as a limitation, but merely as illustrative of the principles of the invention, the scope of which is defined in the appended claims.

WHAT IS CLAIMED IS:

Per B

1. In a modulated carrier current signaling system employing a carrier-current amplifier and rectifier and a modulation current amplifier, which rectifier produces a modulated uni-directional voltage, the method of operating said system which comprises utilizing the modulated component of said voltage to actuate said modulation current amplifier and simultaneously to regulate the carrier-current amplification by applying the uni-directional component of said voltage to an element of said carrier-current amplifier.

2. In a modulated carrier-current signaling system employing a carrier-current amplifier and rectifier, which rectifier produces a modulated uni-directional voltage, a direct-current connection from said rectifier to an element of said amplifier, whereby the amplification is regulated automatically, and a connection from said rectifier to a modulation current responsive device.

3. In a modulated carrier-current signaling system employing a carrier-current amplifier and rectifier, which rectifier produces a modulated uni-directional voltage, a direct-current connection from said rectifier to an element of said amplifier, whereby the amplification is regulated automatically, and a connection from said rectifier to a modulation current amplifier whereby the signal is further amplified.

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4. In a modulated carrier-current signaling system employing a carrier-current amplifier and rectifier, which rectifier produces a modulated uni-directional voltage, a direct-current connection from said rectifier to an element of said amplifier for applying to a control electrode of said amplifier a biasing voltage derived from the output circuit of said rectifier, whereby the amplification is regulated automatically and a connection from said rectifier to a modulation current amplifier whereby the signal is further amplified.

5. In a carrier-current signaling system employing an amplifier and a two-electrode rectifier, the method of operating said system which comprises rectifying said carrier-current to produce a uni-directional voltage directly proportional to the carrier-voltage, and utilizing said uni-directional voltage to regulate the amplification by applying said uni-directional voltage to an element of said amplifier.

6. In a modulated carrier-current signaling system employing a carrier-current amplifier and two-electrode rectifier and a modulation-current amplifier, which rectifier produces a modulated uni-directional voltage, the method of operating said system which comprises utilizing said voltage to actuate said modulation current amplifier and simultaneously to regulate the carrier-current amplification by applying said voltage to an element of said carrier-current amplifier.

7. A signaling system employing an amplifier coupled to a two-electrode rectifier, which rectifier produces a uni-directional voltage directly proportional to the impressed alternating-current voltage, and a direct-current connection from said rectifier to an element of said amplifier, whereby the amplification is regulated automatically by means of said proportional uni-directional voltage.

8. A modulated carrier-current signaling system employing a carrier-current amplifier and a two-electrode rectifier, which rectifier produces a modulated uni-directional voltage, and a direct-current connection from said rectifier to an element of said amplifier, whereby the ~~amplifier~~ is regulated automatically by means of said uni-directional voltage, and a connection from said rectifier to a modulation current amplifier whereby the signal is further amplified.

9. A modulated carrier-current signaling system employing a carrier-current amplifier and two-electrode rectifier, which rectifier produces a uni-directional biasing voltage directly proportional to the carrier-current voltage, a direct-current connection from said rectifier to an element of said amplifier for applying said biasing voltage to a control electrode of said amplifier, whereby amplification of said carrier-current amplifier is automatically regulated inversely in proportion to said carrier current voltage.

10. In a modulated carrier-current signaling system, a carrier-current amplifier having a control electrode, an anode and a cathode, and connected to the output of said amplifier a rectifier which produces in its output a modulated voltage having a direct-current component, a direct-current connection from the output of said rectifier to the control electrode of said amplifier and filtering means for causing the voltage delivered from said rectifier to said control electrode to be substantially free from modulation voltage components.

11. In a signaling system a vacuum tube amplifier having a cathode and a control electrode, a vacuum tube detector coupled to said amplifier, said detector having an output electrode, means for maintaining said output electrode normally negative relative to at least part of said amplifier cathode, means for causing said output electrode to become more negative in the presence of an amplified signal, and a direct-current connection between said control electrode and said output electrode, whereby the amplification of said amplifier is regulated automatically.

12. In a carrier-current signaling system, in combination, a vacuum tube amplifier having a cathode and a control electrode, a vacuum tube detector coupled directly to the output of said amplifier, said detector having a cathode and an output electrode, means for maintaining said detector cathode at substantially the same potential as said amplifier cathode, means for maintaining said output electrode at a negative potential with respect to said cathodes, means causing said output electrode to become more negative in the presence of an ~~amplifier~~ signal, and a direct-current connection between said output electrode and said control electrode.

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3 13. A combination according to Claim 11 in which the means for maintaining the detector output electrode at a negative potential with respect to said cathodes is a resistance connected between said output electrode and the detector cathode.

14. Apparatus in accordance with Claim 3 in which said direct-current connection from said rectifier to an element of said amplifier includes a resistance in series and a capacity in shunt thereto for filtering out the modulation component and preventing modulation voltages from reaching said amplifier element.

Insert B

~~15. Apparatus in~~ accordance with Claim 8 in which said connection from said rectifier to said modulation current amplifier ~~includes~~ a condenser in series for preventing the uni-directional component from being impressed upon the input of said modulation current amplifier.

16. In a modulated carrier current signaling system, a plurality of space discharge devices arranged in tandem for transmitting the modulated carrier current, a rectifier connected to the output of said tandem arrangement for furnishing a uni-directional modulation voltage in the output circuit of said rectifier and a direct current connection from the output of said rectifier to a control element of said space discharge devices for impressing said uni-directional voltage upon said control electrode whereby the intensity of the carrier current signals impressed at the input of said rectifier is automatically maintained substantially constant.

17. In a modulated carrier current signaling system, a plurality of space discharge devices arranged in tandem for transmitting the modulated carrier current, a rectifier connected to the output of said tandem arrangement for furnishing a uni-directional modulation voltage in the output circuit of said rectifier, a modulation current amplifier, a direct current connection from the output of said rectifier to a control element of said space discharge devices for impressing said uni-directional voltage upon said control electrode whereby carrier current signal intensity at said rectifier is automatically maintained substantially constant, and a connection from the output of said rectifier to said modulation current amplifier for impressing the modulation output of said rectifier upon said modulation current amplifier.

18. Apparatus in accordance with claim 17 wherein said rectifier is the two-element type, [illegible] the amplitude of said carrier current signal at [illegible] rectifier is maintained substantially [illegible]

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IN [illegible] I affix my signature.

Inventor's [illegible]

STATE OF NEW YORK

COUNTY OF NEW YORK

I, HAROLD [illegible],

the above-named petitioner, being [illegible] sworn, [illegible] and say that I am a citizen of the United States, and a resident of 38-22nd St., Jackson Heights, [illegible], that I verily believe myself to be the original, [illegible] inventor of the improvements in

[illegible]

described and claimed in the annexed specification which is a division of my original application Serial No. [illegible], filed July 7, 1927; that I [illegible] believe that the same was ever known or used [illegible] invention or discovery thereof, or patented [illegible] in any printed publication in any [illegible] discovery thereof, [illegible] or [illegible] years prior to [illegible] has not been patented [illegible] United States [illegible] twelve [illegible] said original application [illegible] patent on said improvements [illegible] representatives or assigns in any country [illegible] States, except that applications [illegible] said original application have been filed [illegible] as follows: Canada,

[illegible]

Subscribed and sworn to before me this [illegible] day of November, 1950.

[illegible]

C 3871
Div. of
Appln.
Ser. No.
203,879

IN THE UNITED STATES PATENT OFFICE

NOV 13

In re application of

HAROLD A. WHEELER :

Division of Application : VOLUME CONTROL

Serial No. 203,879 :

Filed July 7, 1927 : November 11th, 1930

Honorable Commissioner of Patents,

Washington, D. C.

S I R:

The above identified application filed concurrently herewith is a division of application Serial No. 203,879, filed July 7th, 1927. The present division is filed to present claims which have been cancelled from the said original application by recent amendment.

Claims 1-4 and 5-9 of the present application are substantially the same as cancelled claims 33-36 and 38-42 respectively of the original application. These claims are directed to the combination of a carrier frequency amplifier, a detector coupled to the output of the amplifier and a d.c. connection from the output of the detector to an element of a preceding space discharge device for effecting automatic volume control. The claims now remaining in the original application are specific to a species calling for visual means for indicating the condition of resonance in the tuning circuits.

Since claims 33-36 and 38-42 of the original application were rejected in the Office Action of October 7th, 1930 in that case, it is deemed advisable in the interest of a speedy prosecution of the present application to deal with these rejections relative to the corresponding claims 1-4 and 5-9 of the present application.

The rejection is based on Robinson patent No. 1,733,824, October 29th, 1929, and specifically on Fig. 6 of that patent. In referring to that Figure, the Examiner stated;

> "The transformer coupling 23 is coupled to the grid circuit of the amplifier to provide automatic regulation by the uni-directional voltage of the amplification and the coupling 20 transfers the signal to the receivers or to an amplifier 21 as shown in Fig. 5 thereof."

It should be obvious, however, that the coupling from the output of detector 14 cannot transmit the uni-directional component of the rectified signal to the grid of amplifier tube 19; for the uni-directional component of the rectified signal flows in the primary of transformer 23 and not in the secondary. The secondary winding of the transformer 23 carries the audio frequency, or modulation, component, just as the secondary of transformer 20 does, and this audio frequency component is the voltage which is applied to the amplifier grid. In the present invention it is desired to prevent this audio component from reaching the amplifier grid; and filtering means are provided for doing this. It is the purpose of this invention to control the amplification in accordance with the d.c. component, which varies as the received signal strength, and not in accordance with an audio variation. Hence, volume control by means of the Robinson system, in the manner contemplated by the present invention, is entirely impossible.

A study of the Robinson patent, moreover, shows that the purpose of that invention is not to secure volume control in the sense of reducing the amplification to compensate for increased signal strength; but rather, it is to increase the amplification in the presence of a signal and thereby to further augment the signal. This is brought out in the patent on page 1, lines 41-48 and page 2, lines 112-124, wherein it is stated that the antenna decrement or rate of damping of the received oscillations is decreased when the signal is increasing in strength.

Referring specifically to the claims in this application, claims 1 and 5 clearly distinguish from Robinson by calling for applying the uni-directional component of the rectifier voltage to an element of the amplifier. As stated above, in the Robinson system the uni-directional component could not be applied to the amplifier because of the coupling through transformer 23.

Claims 2-4 and 7-12, 16 and 17 call for a direct current connection from the rectifier to an element of the amplifier for automatically regulating amplification. Robinson's transformer coupled connection is certainly not a direct current connection.

Claim 6 calls for a two-element rectifier which produces a modulated uni-directional voltage and utilizing the said modulated uni-directional voltage to actuate a modulation current amplifier and simultaneously to regulate the carrier current amplification. In the Robinson system it is clear that the uni-directional modulated voltage is not utilized to actuate the modulation current amplifier or to regulate the carrier current amplification; it is only the modulated component free from the uni-directional component which is utilized for any purpose.

Claim 13 is dependent upon claim 12, claims 14 and 15 are dependent upon claim 3, and claim 18 is dependent upon claim 17; and since claims 3, 12 and 17 have been shown above to clearly distinguish from Robinson, claims 13, 14, 15 and 17 are clearly distinct.

The Examiner has objected to claims 38-42 of the original application (claims 5-[illegible] of the present application) on the ground that the expression "two-electrode" rectifier is unwarranted because all the Figures of the drawings disclose a three-electrode detector. It is submitted however,

that the rectifiers 33, 64 and 64 of Figures 1, 3 and 7 are in fact two-electrode rectifiers; for while the rectifiers are drawn in form as three-element space discharge devices and show three elements, the tieing together of the grid and plate clearly makes the device a two-element device. Certainly such a device has no other elements then an anode and a cathode. It is immaterial how many separate structures are tied together to constitute an anode. For example, it is common practice to construct vacuum tubes having two plates, one on each side of the cathode, the two plates being electrically connected to constitute one anode. Yet, in illustrating and discussing such a device it is the practice to show and speak of only one anode and not two. The reason why the present illustrations show the grid and a plate tied together to constitute an anode, is that many commercial tubes suitable for use as the two-element rectifier of the present invention are constructed in form as three-element tubes.

The Examiner contended that the "substitution of a detector having directly connected grid and plate in the Robinson system would not involve invention since this type of detector is well known and introduces no new function in the volume control system." Applicant contends, however, that the use of a two-element detector does involve invention over a three-element detector.

As is clearly pointed out in the specification in page 24 line 1, to page 25 line 8, the use of a two-element detector provides a linear ratio between the rectified response and the modulated carrier current signal and thus enables the carrier wave at the output of the amplifier to be maintained at a substantially constant amplitude. The d.c. component of the rectified response is proportional to the

carrier amplitude and independent of modulation; so the modulation component of the rectified response is proportional to the percentage modulation of the carrier wave. In the case of a "square-law" detector, on the other hand, the d.c. component of the rectified response increases with an increase of the percentage modulation of the carrier; which means that the carrier amplitude is varied in accordance with the rise and fall of the amplitude of the modulation component. This sort of control is undesirable because such a variation of the carrier introduces a modulation distortion and furthermore tends to maintain the audio response at a more constant volume level than the actual changes in the modulation amplitude which are transmitted. Since these undesirable results are avoided by the use of a "linear" detector, it clearly amounts to invention to use such a detector as a part of a volume controlling arrangement.

Falkner patent No. 1,698,014 was cited, although no claims were rejected on it. Although the system disclosed by Falkner relates to volume control it has no bearing upon the claims of this invention. Volume control is effected by Falkner by means of a regenerative detector, the amount of regeneration of which is varied inversely as the received signal intensity. The apparatus required to vary the regeneration includes another radio receiver, the output tube of which is shunted across the regenerative impedance. This system is obviously entirely different from this invention.

Respectfully submitted,

Pennie Davis Marvin and Edmonds
Attorneys for Applicant.

PENNIE, DAVIS, MARVIN & EDMONDS

Div. 51 Room 240-Annex 260 Paper No. 3

Address only The Commissioner of Patents, Washington, D. C., and not any official by name

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON June 30, 1931.

All communications respecting this application should give the serial number, date of filing, and name of the applicant.

JUN 30 1931

Please find below a communication from the EXAMINER in charge of this application.

Thomas E. Robertson
Commissioner of Patents

Pennie, Davis, Marvin & Edmonds,
165 Broadway,
New York, N. Y.

Applicant: H. A. Wheeler
Ser. No. 495,386
Filed Nov. 13, 1930
For Volume Control

This application has been examined.

Record is made of:

Carter	1,739,351	Dec. 10, 1929	250-20.45
Friis	1,675,848	July 3, 1928	250-20.45a
Affel	1,511,015	Oct. 7, 1924	250-2-F.C.

Claims 1-4, inclusive, 10, 14, 16 and 17 are each rejected on the reference to Friis cited. The connection through the valves 15 and 16 and the resistance 18 is considered the full equivalent of applicant's direct current connection since it performs the same function in the same way.

Claims 5, 6, 7, 8, 9 and 18 are each rejected on the reference to Friis in view of Carter. No invention is seen in substituting for the rectifier of Friis the two electrode rectifier as shown to be old at 11 of Carter.

Claims 11, 12, 13 and 15 are considered allowable as at present advised.

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O. D. Backus
Examiner

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IN THE UNITED STATES PATENT OFFICE

In re application of :
HAROLD A. WHEELER :
Serial No. 495,386 : VOLUME CONTROL
Filed Nov. 13, 1930 :
Div. 51 Room 240-A. :

New York, N. Y., July 15, 1931.

Honorable Commissioner of Patents,
Washington, D. C.

S i r:

I, HAROLD A. WHEELER, the applicant above identified, state my residence and post office address to be No. 18 Melbourne Road, Great Neck, Long Island, County of Nassau, in the State of New York.

C-3871

DEC 12 31

IN THE UNITED STATES PATENT OFFICE

- - - - - - - - - - - - - - - -

In re Application of
HAROLD A. WHEELER
Serial No. 495,386
Filed November 13, 1930
Div. 51, Room 240-A

For - VOLUME CONTROL

- - - - - - - - - - - - - - - -

New York, N. Y., December 10, 1931.

Honorable Commissioner of Patents,
Washington, D. C.

Sir:

In response to the Office Action of June 30, 1931, please amend the above identified application as follows:

Cancel Claim 5.

Claim 8, line 6, change "amplifier" to -- amplification --.

Claim 12, line 10, change "amplifier" to -- amplified --.

Page 47, after line 22, insert the following paragraph:

A further advantage of the "linear" type detector with the automatic volume control connection and a visual resonance indicator in the anode circuit of the amplifier whose grid bias is being automatically controlled, lies in

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Objection 2 cont'd

the fact that the visual resonance indicator will give an indication which is proportionate to the received signal intensity. This follows from the fact that the negative grid bias on the amplifier is directly proportional to the strength of the signal; and hence the anode current bears a similar relation to the signal.

Add the following new claims;

(a)

DENNIS, DAVIS, HARVIN & EDMONDS

--~~19.~~ 5 In a signaling system, a vacuum tube amplifier having a cathode and a control electrode, a detector coupled to said amplifier said detector having an output electrode, means for maintaining said output electrode normally negative relative to at least part of said amplifier cathode, means for causing said output electrode to become more negative in the presence of an amplified signal and a direct-current connection between said control electrode and said output electrode, whereby the amplification of said amplifier is regulated automatically.

6 ~~20.~~ In a signaling system a vacuum tube amplifier having a cathode and a control electrode, a second vacuum tube coupled to said amplifier and having an output electrode, means for coupling the output of said amplifier to the said second tube, means for maintaining said output electrode normally slightly negative relative to at least part of said cathode, means for causing said output electrode to become more negative in the presence of an amplified signal, and a direct-current connection between said control electrode and said output electrode, whereby the amplification of said amplifier is regulated automatically.

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7 ~~21.~~ In a signaling system, a vacuum tube amplifier having an anode, a cathode and a control electrode, a detector coupled to said amplifier, said detector having an output electrode, means for maintaining said output electrode normally negative relative to at least part of said amplifier cathode, means for causing the said output electrode to become more negative in the presence of an amplified signal, a tuning arrangement for tuning said amplifier to a desired signal, a direct current connection between said control electrode and said output electrode, whereby the amplification of said amplifier is regulated automatically, ~~and tuning of said tuning arrangement in accordance with the output response of said system is thereby rendered impracticable.~~ and ~~visual~~ means for visually indicating the condition of resonance in said tuning arrangement, whereby tuning is facilitated.

8 ~~22.~~ An arrangement according to claim 7 ~~21~~ in which said tuning arrangement and said ~~visual~~ means for visually indicating the condition of resonance are connected in the anode circuit of said amplifier.

23. In a signaling system, a vacuum tube amplifier having an anode, a cathode and a control electrode, a diode detector coupled to said amplifier, said detector including an output electrode, a tuning circuit associated with said amplifier, a direct-current connection between said output electrode and said control electrode for automatically regulating the amplification of said amplifier whereby tuning of said tuning circuit in accordance with the response of said system is rendered impracticable, and visual means for indicating the condition of resonance in said tuning circuit

24. An arrangement according to claim 23 in which said tuning circuit and said visual means are connected in the anode circuit of said amplifier.

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25. In a signaling system, a vacuum tube amplifier having an anode, a cathode and a control electrode, a detector coupled to said amplifier, said detector producing a rectified output which is directly proportional to the signal voltage applied thereto, a direct-current connection between the output of said detector and said control electrode for automatically regulating the amplification of said amplifier, a tuning circuit for selecting the signal to be amplified by said amplifier and visual means for indicating the condition of resonance in said tuning circuit, whereby said visual means gives an indication of the strength of the received signal.

26. A modulated carrier current signaling system comprising a carrier current amplifier and a detector, which detector produces a modulated uni-directional voltage and a direct current connection from the output circuit of said detector to an element of said carrier current amplifier for regulating the amplification automatically by means of said uni-directional voltage, a tuning arrangement associated with said carrier current amplifier, and visual means for indicating the condition of resonance in said tuning arrangement.

27. In a signaling system a vacuum tube amplifier having a cathode and a control electrode, a vacuum tube detector coupled to the output of said amplifier, said detector having a cathode and an output electrode, means for maintaining said detector cathode at a potential greater negative relative to said amplifier cathode, means for maintaining said output electrode at a potential normally slightly negative relative to said amplifier cathode, means for causing said output electrode to become more negative in the presence of an amplified signal, and a direct-current connection between said output electrode and said control electrode whereby the amplification of said amplifier is regulated automatically.

R E M A R K S

The Official Draftsman is requested in a separate letter to amend Fig. 1 of the drawings to cause numeral 43 to designate the grid of tube 39, and to indicate the "Feed Point" by an arrow.

The Examiner has rejected most of the claims of this application upon Friis patent 1,675,848, the Examiner's contention being that the connection from Friis' detector 7 "through the valves 15 and 16 and the resistance 18 is considered the full equivalent of Applicant's direct-current connection since it performs the same function in the same way."

It is respectfully submitted, however, that the Examiner's contention is not quite correct. While it is true that Applicant's system performs the same general function as Friis' system, that is, controls the amplification by biasing the control electrode of a radio frequency amplifier by means of the rectified output from a rectifier, yet it is not true that this function is performed "in the same way" in Applicant's system as in the Friis system.

The Friis arrangement comprises carrier-frequency amplifiers 3 and 4, an amplifier-detector 7 and a low-frequency amplifier 8 which receives the modulation components from the output of detector 7. Friis' volume [illegible] comprises a connection from the output of detector 7 [illegible] a network consisting of condenser 13 and inductance 14 [illegible] resonant at the carrier frequency, a carrier-frequency amplifier 15, a rectifier 16 and a resistance [illegible] put circuit of the rectifier. [illegible] carrier frequency [illegible] (see [illegible]) [illegible] the amplifier 15 [illegible] modulation components. Therefore, the output current of the rectifier 16, which flows through resistance 18 is unmodulated (see Friis specification, page 2, lines 65 [illegible]

two detectors, or rectifiers, one carrying the modulation component which is supplied to the low-frequency amplifier, and the other carrying no modulation component, but merely furnishing a steady direct current dependent upon the amplitude of the carrier wave.

Applicant's system, on the other hand requires only a single rectifier, or detector, which simultaneously performs the functions of both the rectifiers of Friis' arrangement. Due to the fact that Applicant has devised a volume control system requiring only a single detector, the multitude of circuit elements, such as tubes 15 and 16 and the associated elements of Friis patent, are rendered unnecessary. Due to this great saving of circuit elements, the system of this application is a distinct [illegible] that of Friis. Surely, the Friis volume [illegible] with its multitude of circuit elements, [illegible] sidered "the full equivalent of Applicant's direct current connection", [illegible]

were attempted to combine the functions of Friis' rectifier tubes 16 and 7 into one rectifier tube, there must be devised some way of supplying anode potential to such single rectifying tube and still enable a potential to be applied upon the grids of the radio frequency amplifier, which is different than ground potential. This would ordinarily require a separate anode battery for the rectifier, or detector. Applicant has devised a system, on the other hand, which requires no source of anode potential for the detector which is separate from that of the other tubes.

At an interview on December 8, 1931, between the Examiner and Applicant's attorney, the Examiner agreed that Applicant has made an invention over Friis and also that the use of the term "direct current connection" to define the connection between the detector and carrier frequency amplifier which term appears in most of the claims, satisfactorily distinguishes from Friis.

The Examiner has rejected claims 5 to 9 and 18 on the reference to Friis in view of the showing of a two-electrode rectifier in Carter patent 1,7[illegible]9,351. It is submitted that these claims are patentable over Friis for the reasons mentioned above in the discussion of the Friis patent. It is further submitted that it is improper to combine Carter with Friis for the purpose of setting forth an anticipation of the claims in question. These claims define more than a mere aggregation of an automatic volume control circuit and a two-electrode rectifier, for the reason that there exists a cooperation between the two-electrode rectifier and the volume control connection composed of a direct current connection from the output of the rectifier to the control electrode of an r.f. amplifier. The proper

operation of such a volume control system comprising this direct current connection requires that the rectifier shall develop a relatively large output, that is, that the change in the uni-directional component in the output of the rectifier corresponding to changes in the signal intensity shall be large enough to produce a considerable biasing effect upon the control electrode of the amplifier. The two-electrode rectifier is peculiarly well-suited for this purpose. There can be utilized sufficiently great radio frequency amplification ahead of the rectifier so that the required intensity at the output of the rectifier will be realized; an inherent characteristic of two-electrode rectifiers is that they are not subject to overloading effects, so almost any desired signal intensity can be applied to the rectifier.

Owing to the extraordinary good results obtained by the use of a two-electrode rectifier in a radio receiver embodying a volume control circuit comprising a d. c. connection, in accordance with this invention, which results have been well borne out in practice, it is believed that there is involved invention in the combinations as recited in [illegible] under rejection.

The Examiner has also cited Affel patent 1,511,015; but this patent is of no great importance in connection with this application, because Affel's volume control connection runs from the output of rectifier R to the input of detector D. The present claims call for a connection to an amplifier and not to a detector. Furthermore, Affel's rectifier R, like that of [illegible], produces a uni-directional component but no modulation component, because of the filter 12, which permits only the carrier to pass to the rectifier.

Referring now to individual groups of claims:

Claim 1 calls for the method of operation which comprises producing a modulated uni-directional voltage by a rectifier and utilizing the modulated component to actuate a modulation current amplifier and a uni-directional component to bias an element of the carrier current amplifier. In the Friis system, the modulation component is furnished by one rectifier, namely, 7, and the uni-directional component is furnished by another rectifier, namely, 16; hence it is clear that claim 1 does not read upon Friis.

Claims 2, 3, 4, and 1[illegible] call for a rectifier which produces a modulated uni-directional voltage, a direct current connection from the rectifier to an element of the amplifier and a connection from the rectifier to a modulation current amplifier. These claims bring out the fact that a single rectifier operates both the modulation current amplifier and the volume control connection. This clearly distinguishes from Friis, inasmuch as Friis does not show a rectifier performing these two functions, and, furthermore, Friis does not show a direct current connection or its equivalent. Clearly the doctrine of equivalents does not apply as to two entirely different systems for effecting a similar result, but rather, applies only to two systems which are of themselves equivalent to each other.

Claims [illegible] and 18 include limitations similar to those of claims 2, 3, and 4 and in addition recite that the rectifier is of the two-electrode type. It is submitted that these claims distinguish from Friis for the reasons discussed above, and also distinguish from Friis in view of Carter because of the extraordinarily new and

useful result attendant upon combining a two-electrode rectifier with a d.c. volume control connection.

Claims 10 and 14 call for a d.c. volume controlling connection between the output of the rectifier, which has a modulated uni-directional component, and the control electrode of the amplifier and also for filtering means to keep the modulation component away from the control electrode. When a volume control connection of the d.c. type in accordance with this claim is utilized, good practice requires that the modulation component be prevented from reaching the control electrode. This cooperation between the filtering means and the direct-current connection should render the claims patentable combinations.

Claim 16 is very similar to claims 2, 3, and 4 except that it does not call for a connection to the modulation current amplifier; accordingly, it is believed to be allowable.

New claims 19 and 20 are very similar to allowed claim 11. Claim 19 is like claim 11 except that it does not contain the limitation that the detector is of the vacuum tube type. The invention can obviously be used with any kind of a detector. Claim 20 is like claim 11 except that the vacuum tube coupled to the amplifier is not called a detector. Applicant believes he is clearly entitled to claim his invention in the manner set forth in claims 19 and 20.

New claims 21 to 25 are directed to the combination of the automatic volume control system of this invention and the visual means for indicating the condition of resonance in the tuning system of the amplifier.

Claims 21 and 22 are like claim 19 except that they include the additional elements of a tuning arrangement and

[redacted]

Reconsideration and allowance of claims 1 to 4, [illegible] to 10, 14, and 16 [illegible] respectfully requested. Reconsideration and allowance of new claims 17 to 26 are also requested. Claims 11 to 13, and 15 stand allowed.

Respectfully submitted,

[illegible]

Attorneys for Applicants.

DEC 12 31

IN THE UNITED STATES PATENT OFFICE

In re Application of	
HAROLD A. WHEELER	
Serial No. 495,386	For - VOLUME CONTROL
Filed November 13, 1930	
Div. 51, Room 240-A	

PENNIE DAVIS MARVIN & EDMONDS

New York, N. Y., December 10, 1931.

Honorable Commissioner of Patents,

Washington, D. C.

ACCOUNT

Sir:

Attention of Official Draftsman

Will you kindly amend Figure 1 of the drawings of the above identified application by connecting numeral 43 with the grid of tube 39 instead of to the tube itself. Also, please amend the same Figure by placing an arrow at "Feed Point" to designate the point of connection of resistance 53 with condenser 40. These changes are indicated in red ink on the attached photostatic copy of Fig. 1.

The cost of this work should be charged to our deposit account.

Respectfully submitted,

Pennie Davis Marvin & Edmonds

Attorneys for Applicant.

CORRECTION ORDERED MAY 23 1932 ACCOUNT

DIV. G CORRECTED MAY 23 1932

PRINT RETURNED BY DRAFTING DIV

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C.3871

IN THE UNITED STATES PATENT OFFICE

DEC 30 31

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In Re Application of :

HAROLD A. WHEELER :

Serial No. 495,386 : For - VOLUME CONTROL

Filed November 13, 1930 :

Div. 51, Room 240-A :

- - - - - - - - - - - - - - - - - - x

December 29, 1931

Hon. Commissioner of Patents,

Washington, D.C.

S I R:

It is respectfully requested that the Supplemental Oath submitted herewith be entered in the file of the above entitled application. The purpose of this Oath is to cover the new claims submitted by amendment filed December 12, 1931.

Respectfully submitted.

Attorneys for Applicant

C. 3871

IN THE UNITED STATES PATENT OFFICE

In re Application of
HAROLD A. WHEELER
Serial No. 495,386 — For - VOLUME CONTROL
Filed November 13, 1930
Div. 51, Room 240-A

SUPPLEMENTAL OATH

STATE OF NEW YORK)
: ss:
COUNTY OF [illegible])

I, HAROLD A. WHEELER, the above named Applicant, being duly sworn, depose and say:

That I am a citizen of the United States and a resident of Great Neck, Long Island, County of Nassau, and State of New York, and that I verily believe myself to be the original, first and sole inventor of the improvements in

VOLUME CONTROL

described and claimed in my above entitled application for United States Letters Patent, Serial No. 495,386, filed November 13, 1930, which is a division of my original application, Serial No. 203,879, filed July 7, 1927, and as claimed in the new claims submitted by amendment filed December 12, 1931; that the subject matter of the said amendment is a part of my invention and was invented before the filing date of my said original application; that I do not know and do not believe that the same was ever known or

used before my invention or discovery thereof, or patented or described in any printed publication in any country before my invention or discovery thereof, or more than two years prior to my said original application, or in public use or on sale in the United States for more than two years prior to my said original application, and has not been abandoned; that said invention has not been patented in any country foreign to the United States on an application filed by me or my legal representatives or assigns more than twelve months prior to my said original application; and that no application for patent on said improvements has been filed by me or my representatives or assigns in any country foreign to the United States, except that applications corresponding to my said original application have been filed as follows:

Canada - Serial No. 339,[illegible]04 - Filed July 5, 1928

Great Britain - Patent No. 293,462 - Filed July 3, 1928

Australia - Patent No. 14,[illegible]90 - Filed July 7, 1928.

Applicant

Subscribed and sworn to before me this 28th day of December, 1931.

[illegible signature]
Notary Public.

Div. 51 Room 5628

Paper No. 7

Address only "The Commissioner of Patents, Washington, D. C." and not any official by name HSM:HCG

All communications respecting this application should give the serial number, date of filing, and name of the applicant

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON May 19, 1932.

Please find below a communication from the EXAMINER in charge of this application. Thomas E. Robertson
Commissioner of Patents

Pennie, Davis, Marvin & Edmonds,
165 Broadway,
New York, N. Y.

Applicant: H. A. Wheeler
Ser. No. 495,386
Filed Nov. 13, 1930
For Volume Control

Responsive to applicant's communications of MAY December 12 and 30, 1931.

Additional record is made of:

Evans	1,736,852	Nov. 26, 1929	250-20.45-uxr
Perry	1,536,130	May 5, 1925	"
Fleming	954,619	Apr. 12, 1910	250-27x

Claims 1-4, inclusive, 10, 14, 16, 17 and 27 are each rejected as being fully met by Evans who shows a detector 16, a resistance 47 in the output thereof and a direct current connection from the resistance to the grids of the amplifier tubes.

Claims 6-9, inclusive, and 18 are each rejected on Evans in view of each of the references to Carter and Fleming. No invention is seen in providing Evans with a two electrode rectifier in view of either Carter or Fleming.

Claims 23-26, inclusive, are each rejected on the reference to Evans in view of Perry. No invention is seen in providing Evans with a tuned input and a visual resonance indicating means as shown old in Perry.

Claims 11, 12, 13 and 15 stand allowed.

Claims 19-22 are considered allowable as at present advised.

HM

C. D. Baxter

C-3871

IN THE UNITED STATES PATENT OFFICE.

In re application of)
HAROLD A. WHEELER,)
Serial No. 495,386,) For: VOLUME CONTROL.
Filed November 13, 1930,)
Division 51, Room 5628.)

PENNIE, DAVIS, MARVIN & EDMONDS

Honorable Commissioner of Patents,
Washington, D. C.

S i r:

In response to the Office Action of May 19, 1932, please amend the above identified application as follows:

Claim 15, line 1, cancel "Apparatus in accordance with Claim 3 in which" and substitute therefor -- In a modulated carrier-current signalling system employing a carrier-current amplifier and rectifier, which rectifier produces a modulated uni-directional voltage, a direct-current connection from said rectifier to an element of said amplifier whereby the amplification is regulated automatically, and a connection from said rectifier to a modulation current amplifier whereby the signal is further amplified, ~~the~~ .

Line 3, change "includes" to -- including --

Cancel claims 1 to 4, inclusive, 6 to 10, inclusive, 14, 16, 17, 18 and 23 to 26, inclusive, without prejudice.

REMARKS

Allowed claim 15 is amended merely to make it independent of claim 3 upon which it was originally dependent.

The cancellation of the claims mentioned above is believed to place this application in condition for allowance. Although applicant does not concur with the Examiner in his contention that all of the claims cancelled hereby are anticipated by the references cited against them, nevertheless, the application is being put in condition for allowance because the allowed claims are believed to afford a substantial measure of protection.

Attention is called to the fact that claim 27, although rejected in the last Office Action, is not cancelled hereby, and is clearly allowable over Evans patent No. 1,736,852 upon which it was rejected. The status of claim 27 was discussed verbally between the Examiner and a representative of applicant's attorneys on June 8, 1932, at which time the Examiner agreed that the claim would be allowed, and in fact, placed a pencil allowance notice beside the claim, in the file.

Briefly, the situation with regard to claim 27 is this: Claim 27 was added to the present application by

amendment filed December 12, 1931, and it was stated in page 11 of that amendment that claim 27 is identical with cancelled claim 4 of applicant's co-pending application Serial No. 494,558, filed November 10, 1930, which claim was allowed in the said co-pending application. In an amendment filed on the same date in the co-pending application Serial No. 494,558, claim 4 was accordingly cancelled. It should be noted that the said claim 4 was again mentioned as being allowed, in a recent Office Action in that application; but this last allowance of claim 4 was obviously a mistake, and mention is made of the fact in an amendment to be filed in that case approximately concurrently herewith.

Claim 27 is doubtless clearly patentable over the reference to Evans patent for the same reason that other claims in the case have been allowed over Evans, the novelty of the claim being clearly set forth in the portion which reads:

> " --- means for maintaining said detector cathode at a potential greatly negative relative to said amplifier cathode, means for maintaining said output electrode at a potential normally slightly negative relative to said amplifier cathode, means for causing said output electrode to become more negative in the presence of an amplified signal ---".

The limitations, just recited, appear in one form or another in the other allowed claims in the case.

Since this amendment places the application in condition for allowance, an early notice of allowance is requested.

Respectfully submitted,

Darby, Davis, Marvin & Edmonds

Attorneys for Applicant.

Dated: New York, N. Y.,
July 22, 1932.

Div. 51, Room 5628
ADDRESS ONLY
THE COMMISSIONER OF PATENTS
WASHINGTON, D. C.

181

Serial No. 495,386

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON

Harold A. Wheeler, Assor. to
Hazeltine Corporation, a Corp. of Delaware.

August 3, 1932.

Your APPLICATION for a patent for an IMPROVEMENT in
VOLUME CONTROL

filed Nov. 13, 1930 has been examined and ALLOWED with 9 claims.

The final fee, TWENTY-FIVE DOLLARS, WITH $1 ADDITIONAL FOR EACH CLAIM ALLOWED IN EXCESS OF 20, must be paid not later than SIX MONTHS from the date of this present notice of allowance. If the final fee be not paid within that period, the patent will be withheld, but the application may be renewed within one year after the date of the original notice with a renewal fee of $25 and $1 additional for each claim in excess of 20.

The office delivers patents upon the day of their date, on which date their term begins to run. The preparation of the patent for final signing and sealing will require about four weeks, and such work will not be begun until after payment of the necessary final fee.

When the final fee is paid, there should also be sent, DISTINCTLY AND PLAINLY WRITTEN, the name of the INVENTOR, TITLE OF THE INVENTION, AND SERIAL NUMBER AS ABOVE GIVEN, DATE OF ALLOWANCE (which is the date of this circular), DATE OF FILING, and, if assigned, the NAMES OF THE ASSIGNEES.

If it is desired to have the patent issue to an ASSIGNEE OR ASSIGNEES, an assignment containing a REQUEST to that effect, together with the FEE for recording the same, must be filed in this office on or before the date of payment of the final fee.

After issue of the patent, uncertified copies of the drawings and specifications may be purchased at the price of TEN CENTS EACH. The money should accompany the order. Postage stamps will not be received.

The final fee will NOT be received from other than the applicant, his assignee or attorney, or a party in interest as shown by the records of the Patent Office.

NOTICE. WHEN THE NUMBER OF CLAIMS ALLOWED IS IN EXCESS OF 20, NO SUM LESS THAN $25 PLUS $1 ADDITIONAL FOR EACH CLAIM IN EXCESS OF TWENTY CAN BE ACCEPTED AS THE FINAL FEE.

Respectfully,

Thomas E. Robertson
Commissioner of Patents.

Pennie, Davis, Marvin & Edmonds,
165 Broadway,
New York, N. Y.

IF PAID ON OR AFTER JULY 31, 1932, THE FINAL FEE WILL BE $30, AND $1 FOR EACH CLAIM IN EXCESS OF 20.

IN REMITTING THE FINAL FEE GIVE THE SERIAL NUMBER AT THE HEAD OF THIS NOTICE.

UNCERTIFIED CHECKS WILL NOT BE ACCEPTED.

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON

RULE 78:

Thomas E. Robertson

C-3?71 [illegible]

IN THE UNITED STATES PATENT OFFICE.

In re Application of
HAROLD A. WHEELER
Serial No. [illegible]
Filed November 13, [illegible]
Division 51, Room [illegible]

For: VOLUME CONTROL.

AMENDMENT UNDER RULE 78.

Honorable Commissioner of Patents,
Washington, D. C.

Sir:

Permission is respectfully requested under the provision of Rule 78 to amend the above entitled application as follows:

Claim 19, line 2, place a comma after "amplifier".
Line 7, place a comma after "signal".

Claim 20, line 3, cancel "coupled to said amplifier and";
Line 4, in front of "means" insert -- means for coupling the output of said amplifier with said second tube, --.

Claim 21, lines 11-14, cancel "and tuning of said tuning arrangement in accordance with the output response of said system is thereby rendered impracticable";
Line 14, cancel "visual";

Same line, after "for" insert -- visually

Last line, change the period to a comma and add -- whereby tuning is facilitated. --

Claim 22, line 2, cancel "visual";

Same line, after "means" insert -- for visually indicating the condition of resonance --.

Add the following claims:

-- ~~23.~~ In a signaling system, a vacuum tube amplifier having a cathode and a control electrode, a diode detector coupled to said amplifier, said detector having an anode, means for maintaining said anode normally negative relative to at least part of said amplifier cathode, means for causing said anode to become more negative in the presence of an amplified signal, and a direct-current connection between said control electrode and said anode, whereby the amplification of said amplifier is regulated automatically.

~~24.~~ In a signaling system, a vacuum tube amplifier having a cathode and a control electrode, a diode detector coupled to said amplifier, said detector having a cathode and an anode, means for maintaining said cathodes at substantially the same potential, means including a high resistance connected between the detector anode and cathode for maintaining said anode normally slightly negative relative to said cathodes, means for causing said anode to become more negative in the presence of an

amplified signal, and a direct-current connection between said control electrode and said anode, whereby the amplification of said amplifier is regulated automatically.

12 ~~30.~~ In a signaling system a vacuum tube amplifier having a cathode and a control electrode, a second vacuum tube having an output electrode, means for coupling said amplifier with said second tube, means for maintaining said output electrode normally slightly negative relative to at least part of said cathode, means for causing said output electrode to become more negative in the presence of an amplified signal, a tuning arrangement for tuning said amplifier to a desired signal, and a direct-current connection between said control electrode and said output electrode, whereby the amplification of said amplifier is regulated automatically, and means for visually indicating the condition of resonance in said tuning arrangement whereby tuning is facilitated. Fig

R E M A R K S

The amendments in claim 20 are introduced to more accurately define the scope of the invention; while the amendments in claims 21 and 22 are made to more accurately designate the means for visually indicating the condition of resonance.

New claims 28 and 29 are practically the same as allowed claim 11, except that they are more specific. Claim 28 is just like claim 11 except that in claim 28 the

detector is specifically referred to as being a diode of which the output electrode is the anode. Claim 29 likewise states that the detector is a diode. The claim is further limited by reciting that the cathodes are all at the same potential and by stating that the means for maintaining the anode normally slightly negative relative to the cathodes includes a high resistance connected between the detector anode and cathode.

New claim 30 is based on allowed claims 20 and 21. The claim is very similar to claim 20 except that there is also recited the tuning arrangement and the means for visually indicating the condition of resonance therein, as recited in claim 21.

Since the new claims are obviously more specific than allowed claims 11 and 20, no additional search is required; and it is, therefore, believed that the claims will be readily admitted.

Respectfully submitted,

Pennie Davis Marvin and Edmonds
Attorneys for Applicant.

New York, N. Y.,
August 18, 1932.

A D Backus

ENTRY APPROVED

ACTING COMMISSIONER OF PATENTS

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#4
Sup oath

U.S. PATENT OFFICE
AUG 1 1932

C-3871

IN THE UNITED STATES PATENT OFFICE.

In re Application of HAROLD A. WHEELER Serial No. 495,386 Filed November 13, 1930 Div. 51, Room 240-A	For VOLUME CONTROL.

SUPPLEMENTAL OATH.

STATE OF NEW YORK)
: ss:
COUNTY OF)

PENNIE DAVIS MARVIN & EDMONDS

I, HAROLD A. WHEELER, the above named Applicant, being duly sworn, depose and say:

That I am a citizen of the United States and a resident of Great Neck, Long Island, County of Nassau and State of New York, and that I verily believe myself to be the original, first and sole inventor of the improvements in

VOLUME CONTROL,

described and claimed in my above entitled application for United States Letters Patent, Serial No. 495,386, filed November 13, 1930, which is a division of my original application, Serial No. 203,879, filed July 7, 1927; and as claimed in the new claims numbered 25 to 30 submitted by amendment filed concurrently herewith; that the subject matter of the said amendment is a part of my invention and was invented before the filing date of my said original

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application; that I do not know and do not believe that the same was ever known or used before my invention or discovery thereof, or patented or described in any printed publication in any country before my invention or discovery thereof, or more than two years prior to my said original application, or in public use or on sale in the United States for more than two years prior to my said original application, and has not been abandoned; that said invention has not been patented in any country foreign to the United States on an application filed by me or my legal representatives or assigns more than twelve months prior to my said original application; and that no application for patent on said improvements has been filed by me or my representatives or assigns in any country foreign to the United States, except that applications corresponding to my said original application have been filed as follows:

Canada - Serial No. 339,004 - Filed July 5, 1928

Great Britain - Patent No. 293,462 - Filed July 3, 1928

Australia - Patent No. 14,290 - Filed July 7, 1928.

PENNIE, DAVIS, MARVIN & EDMONDS

Harold A. [illegible]
Applicant.

Subscribed and sworn to before me
this 17th day of August, 1931.

[illegible]
Notary, Public.

71 mes

Div. 51 Room 5628 Paper No. 10

Address only
The Commissioner of Patents
Washington, D. C.
and not any official by name

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE

All communications respecting this application should give the serial number, date of filing, and name of the applicant

MCQ WASHINGTON August 19, 1932.

H. A. Wheeler
495,386
Nov. 13, 1930
Volume Control

Pennie, Davis, Marvin & Edmonds,
165 Broadway,
New York, N. Y.

[signature]
Commissioner of Patents.

6

12

C 3871

B

FINAL FEE PAID TO THE COMMISSIONER OF PATENTS

(Be careful to give correct Serial No.)

Serial No. 49[illegible],386

INVENTOR:

[illegible]AROLD A. [illegible]

PATENT TO BE ISSUED TO

[illegible]

NAME OF INVENTION, AS ALLOWED:

[illegible]

DATE OF PAYMENT:

August [illegible], 19[illegible]

FEE:

[illegible] DOLLA[illegible] ($[illegible])

DATE OF FILING:

November [illegible]

DATE OF CIRCULAR OF ALLOWANCE:

[illegible], 19[illegible]

The Commissioner of Patents will please apply the accompanying fee as indicated above.

[illegible]

Attorney.

SEND PATENT TO:

[illegible]

[illegible]

Final fees will not be received from other than the applicant, his assignee or attorney, or a party in interest as shown by the records of the Patent Office.

JAN 21 1933
PATENT OF...

District Court of the United States

Southern DISTRICT OF N. Y.

Honorable Commissioner of Patents,
Washington, D. C.

Sir:

In compliance with the Act of February 18, 1922 (42 Stat. L. 392), you are advised that there was filed on the 19th day of January, 1933, in this court an action, suit, or proceeding No. E73-445, entitled:

Name Hazeltine Corporation, Plaintiff,

Address Delaware

versus

Name Howard Radio Co and Graham ... Sullivan, Defendant,

Address Illinois + N. Y.

brought upon the following patents:

PATENT NO.	DATE OF PATENT	PATENTEE
1 1,879,861	9.27.32	Wiff
2 1,879,863	9.27.32	"
3		
4		
5		

In the above-entitled case, on the ______ day of ______, 193 , the following patents have been included by ______ (insert amendment, answer, cross bill, or other pleading):

PATENT NO.	DATE OF PATENT	PATENTEE
1		
2		
3		
4		
5		

In the above-entitled case the following decision has been rendered or decree issued:

IN WITNESS WHEREOF I have affixed my hand this 19th day of Jan., 1933, at N. Y.

Charles Weiser
Clerk of said Court.

District Court of the United States

DISTRICT OF

Sirs:

Name

Address

Name

Address

PATENT NO. DATE OF PATENT

PATENT NO. DATE OF PATENT

PENNIE, DAVIS, MARVIN AND EDMONDS
COUNSELLORS AT LAW
[illegible] BROADWAY
NEW YORK

April [illegible] 1933

[illegible]-5971

[illegible] Commissioner of Patents,
[illegible] Washington, D. C.

In re: Patent of Harold A. Wheeler, [illegible] 1,[illegible],063, granted Sept. 27, 193[illegible], for "Volume Control"

[illegible] attention has just been called to two draftsmen's [illegible] in Fig. 3 and Fig. 4, respectively, of [illegible] above-identified patent. Fig. 3 and Fig. 4 were [illegible] to be exact duplicates of Fig. 3 and Fig. 4 of [illegible] application Ser. No. 203,[illegible]7[illegible], filed July 7th, 1927, [illegible] the present patent is a division.

[illegible] correctly shown in the parent appli-cation [illegible], and the drawing in the present [illegible] indicated in red on the photostat [illegible]

[illegible] the omission of a fixed [illegible] the variable condenser and the

resistance 83 of the input circuit of the tube 58; and in Fig. , the omission of an arrow on the variable tuning condenser connected to the input of the tube 90.

Will you kindly place this letter in the file of the patent, in order that these draftsman's errors may be duly recorded.

Respectfully,

Pennie, Davis, Marvin & Edmonds,

Form 780

District Court of the United States

Southern DISTRICT OF N.Y.

HONORABLE COMMISSIONER OF PATENTS,
Washington, D. C.

SIR:

In compliance with the Act of February 18, 1922 (42 Stat. L. 392), you are advised that there was filed on the 19th day of January, 1933, in this court an action, suit, or proceeding No. E 73-445, entitled:

Name Hazeltine Corporation, Plaintiff,

Address Delaware

versus

Name Howard Radio Co. and Archie L. Sullivan, Defendant,

Address Illinois & N.Y.

brought upon the following patents:

PATENT NO.	DATE OF PATENT	PATENTEE
1 1,877,861	9/21/32	pltff
2 1,877,863	9/21/32	"
3		
4		
5		

In the above-entitled case, on the ______ day of ______, 193__, the following patents have been included by ______ (insert amendment, answer, cross bill, or other pleading):

PATENT NO.	DATE OF PATENT	PATENTEE
1		
2		
3		
4		
5		

In the above-entitled case the following decision has been rendered or decree issued:

1/14/33 Order dismissing cause as to Howard Radio Co.
4/33 and dismissing cause without prejudice as to Archie L. Sullivan

IN WITNESS WHEREOF I have affixed my hand this 24th day of May, 1933, at N.Y.

Charles Weiser
Clerk of said Court.

Tightly Bound

Form 789

District Court of the United States

Southern DISTRICT OF N.Y.

HONORABLE COMMISSIONER OF PATENTS,
Washington, D.C.

SIR:

In compliance with the Act of February 18, 1922 (42 Stat. L. 392), you are advised that there was filed on the 14th day of Feb 1933 in this court an action, suit, or proceeding No. E 76-293, entitled

Name Hazeltine Corp Plaintiff,

Address Delaware

versus

Name York Automotive Distributing Co Inc Defendant,

Address N.Y.

brought upon the following patents:

PATENT NO.	DATE OF PATENT	PATENTEE
1. 1,879,863	9/27/32	Pltff
2. 1,755,114	4/15/30	"
3. 1,755,115	4/15/30	"
4.		
5.		

In the above-entitled case, on the day of 193 , the following patents have been included by (insert amendment, answer, cross bill, or other pleading):

PATENT NO.	DATE OF PATENT	PATENTEE
1.		
2.		
3.		
4.		
5.		

In the above-entitled case the following decision has been rendered or decree issued:

IN WITNESS WHEREOF I have affixed my hand this 14th day of Sept 1933 at N.Y.

Charles Weiser
Clerk of said Court.

495386

80

Form 786

District Court of the United States

Eastern DISTRICT OF New York

HONORABLE COMMISSIONER OF PATENTS,
Washington, D. C.

SIR:

In compliance with the Act of February 18, 1922 (42 Stat. L. 402) you are advised that there was filed on the 28th day of September 1933, in this court an action, suit, or proceeding No. E-7077 entitled

Name Hazeltine Corporation Plaintiff,
Address Jersey City, Hudson County, New Jersey

versus

Name Dareya-City Radio, Inc. et al Defendant,
~~Address~~ Flushing, L. I.

brought upon the following patents:

	PATENT NO.	DATE OF PATENT	PATENTEE
1	1,879,863	Sept. 27, 1932	Hazeltine Corporation
2			
3			
4			
5			

In the above entitled case, on the day of 193 , the following patents have been included by insert amendment, answer, cross bill, or other pleading:

	PATENT NO.	DATE OF PATENT	PATENTEE
1			
2			
3			
4			
5			

In the above entitled case the following decision has been rendered or decree issued:

IN WITNESS WHEREOF I have affixed my hand this 28th day of September 1933 at Brooklyn, N.Y.

Percy G. B. Gerkes
Clerk of said Court.

by St. Fener
Deputy Clerk

Form 780

District Court o. the United States

Southern DISTRICT OF N.Y.

HONORABLE COMMISSIONER OF PATENTS,
Washington, D.C.

SIR:

In compliance with the Act of February 18, 1922 (42 Stat. L., 392), you are advised that there was filed on the 28th day of Sept, 1933, in this court an action, suit, or proceeding No. E 76 311 entitled

Name Hazeltine Corp, Plaintiff,

Address Delaware

versus

Name Westinghouse Electric Supply Co Inc. New York, Defendant,

Address [illegible] New Jersey

brought upon the following patents:

PATENT NO.	DATE OF PATENT	PATENTEE
[illegible]	[illegible]	[illegible]

In the above-entitled case on the day of , 193 , the following patents have been included by (insert amendment, answer, cross bill or other pleading):

PATENT NO.	DATE OF PATENT	PATENTEE

In the above-entitled case the following decision has been rendered or decree issued:

IN WITNESS WHEREOF, I have affixed my hand this 28th day of Sept, 193 .

[illegible signature]
Clerk of said Court.

District Court of the United States

Eastern DISTRICT OF New York

HONORABLE COMMISSIONER OF PATENTS,
Washington, D.C.

SIR:

In compliance with the Act of February 18, 1922 (42 Stat. L. 392), you are advised that there was filed on the 1st day of March 1933 in this court an action, suit, or proceeding No. E 6873 entitled

Name Hazeltine Corp Plaintiff,

Address 15 Exchange Place, Jersey City, NJ

versus

Name R. E. Thrown Corp et al Defendant,

Address Eastern District of New York

brought upon the following patents:

	PATENT NO.	DATE OF PATENT	PATENTEE
1	1,884,863	Sept-27-1932	Harold A. Wheeler
2			
3			
4			
5			

(Filing of Complaint Reported March 1-1933

In the above-entitled case, on the day of 192 , the following patents have been included by insert amendment, answer, cross bill, or other pleading:

	PATENT NO.	DATE OF PATENT	PATENTEE
1			
2			
3			
4			
5			

In the above-entitled case the following decision has been rendered or decree issued:

Decree favors Pltff. filed & entered October -30- 1933

IN WITNESS WHEREOF, I have affixed my hand this 30th day of October 1933, at Brooklyn, NY

Percy G. B. Gilkes
Clerk of said Court.

By [illegible]
Deputy Clerk

Form 789

District Court of the United States

Eastern DISTRICT OF New York

HONORABLE COMMISSIONER OF PATENTS,
Washington, D. C.

SIR:

In compliance with the Act of February 18, 1922 (42 Stat. L. 392), you are advised that there was filed on the 6th day of January, 1934, in this court an action, suit, or proceeding No. E-7163, entitled:

Name Hazeltine Corp, Plaintiff,

Address 15 Exchange Place, New Jersey

versus

Name R. E. D. Corp, Defendant,

Address Eastern District of N Y

brought upon the following patents:

	PATENT NO.	DATE OF PATENT	PATENTEE
1	1,879,863	Sept 27, 1932	Hazeltine Corp
2			
3			
4			
5			

In the above-entitled case, on the .... day of .... 193 , the following patents have been included by .... (insert amendment, answer, cross bill, or other pleading):

	PATENT NO.	DATE OF PATENT	PATENTEE
1			
2			
3			
4			
5			

In the above-entitled case the following decision has been rendered or decree issued:

IN WITNESS WHEREOF I have affixed my hand this 8th day of January 1934 Brooklyn, N Y

Percy M Bates(?)
Clerk of said Court.

by [illegible],
Deputy Clerk

495[illegible]6

Form 769

District Court of the United States

Southern DISTRICT OF New York

Honorable Commissioner of Patents

Sir:

In compliance with ... on the 19th ... January ...

E 77-152

Name Hazeltine Corporation Plaintiff

Address Delaware

Name ... Defendant

Address ...

brought upon the following patents:

PATENT NO. DATE OF PATENT PATENTEE

1.
2.
3.
4.
5.

In the above entitled case ... the following patents ...

PATENT NO. DATE OF PATENT PATENTEE

1.
2.
3.
4.
5.

District Court [illegible] the United States

Eastern DISTRICT OF New York

[illegible] Commissioner of Patents,
Washington, D.C.

Sir:

[illegible] Act [illegible] 1870 [illegible] Stat. L. 202, you are advised that there was filed

on the 8th [illegible] February 1934 in this court an action, suit, or [illegible]

[illegible] 7177 [illegible]

Name [illegible] Corporation Plaintiff.

Address 15 Exchange Place, [illegible] N. J.

vs

Name Paramount [illegible] System Inc. Defendant.

Address Eastern District of New York

brought upon the following patent:—

PATENT NO.	DATE OF PATENT	PATENTEE
[illegible]	Sept [illegible] 192[illegible]	Harold E. Wheeler

In the above entitled case, on the [illegible] day of [illegible] 193 , the following patents have been included by [illegible] (insert amendment, answer, cross bill, or other pleading):

PATENT NO.	DATE OF PATENT	PATENTEE

In the above entitled case the following decision has been rendered or decree issued:

IN WITNESS WHEREOF, I have hereunto set my hand this 22nd day of [illegible] 1934 [illegible] Brooklyn NY

Percy [illegible]
Clerk of said Court.

by [illegible]
Deputy Clerk

FEB 6 1934

Form 789

District Court of the United States

Eastern DISTRICT OF New York

HONORABLE COMMISSIONER OF PATENTS
Washington, D.C.

SIR:

In compliance with the Act of February 18, 1922 (42 Stat. L. 392) you are advised that there was filed on the 28th day of September 193~~4~~ 3 in this court an action, suit, or proceeding No. E 7077 entitled:

Name Hazeltine Corporation Plaintiff,

Address Jersey City, Hudson County, N.J.

versus

Name Garden City Radio, Inc., and Defendant,

Address Flushing, L.I.

brought upon the following patents:

	PATENT NO.	DATE OF PATENT	PATENTEE
1	1,879,863	Sept-21-1932	Hazeltine Corp.
2			
3	(Filing of Complaint reported		
4	Sept. 28-1933)		
5			

In the above-entitled case, on the day of 193 , the following patents have been included by insert amendment, answer, cross-bill or other pleading:

	PATENT NO.	DATE OF PATENT	PATENTEE
1			
2			
3			
4			
5			

In the above-entitled case the following decision has been rendered or decree issued:

Final Decree favor pltff
filed & entered Feb 2 1934

IN WITNESS WHEREOF, I have affixed my hand this 5th day of February 1934 at Brooklyn, N.Y.

Henry H. Walker
Clerk of the Court.

By [illegible]
Deputy Clerk

District Court of the United States

Eastern DISTRICT OF New York

Honorable Commissioner of Patents,
Washington, D.C.

Sir:

In compliance with the Act of February 18, 1922 (42 Stat. L. 392), you are advised that there was filed on the 9th day of March, 1934, in this court an action, suit, or proceeding No. E-7149 entitled

Name Hazeltine Corporation, Plaintiff,
Address 15 Exchange Place New Jersey

versus

Name Yellow Taxi Corporation, Defendant,
Address Brooklyn, N.Y.

brought upon the following patents:

PATENT NO.	DATE OF PATENT	PATENTEE
1879,863	Sept 27-1932	Hazeltine Corporation

~~In the above-entitled case, on the day of 193 , the following patents have been included by (insert amendment, answer, cross bill, or other pleading):~~

PATENT NO.	DATE OF PATENT	PATENTEE

~~In the above-entitled case the following decision has been rendered or decree issued:~~

IN WITNESS WHEREOF, I have affixed my hand this 9th day of March 1934 at Brooklyn New York

Percy W. Backus
Clerk of said Court.

by S.P. Lener,
Deputy Clerk

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Form 789

District Court of the United States

Eastern DISTRICT OF New York

HONORABLE COMMISSIONER OF PATENTS
Washington, D.C.

SIR:

In compliance with the Act of February 18, 1922, 42 Stat. L. 392, you are advised that there was filed on the 17th day of April 1934, in this court an action, suit, or proceeding No. E 7427 entitled

Name Haydite Corporation Plaintiff

Address 15 Exchange Place, Jersey City, New Jersey

Name Sayre & Fisher Co. and Kings Cooley Co. [illegible] Defendant

Address Eastern District of New York

brought upon the following patents:

PATENT NO.	DATE OF PATENT	PATENTEE
1,255,878	Sept. 7, 1918	[illegible] O. Hayde
2		
3		

In the above-entitled case, on the ____ day of ____ 193__, the following patents have been included by ____ insert amendment, answer, cross-bill or other pleading.

PATENT NO.	DATE OF PATENT	PATENTEE
1		
2		
3		

In the above-entitled case the following decision has been rendered or decree issued:

IN WITNESS WHEREOF, I have affixed my signature this ____ day of April 1934, at Brooklyn, N.Y.

[illegible] Clerk of the Court

[illegible] Deputy Clerk

3-86-89

District Court of the United States

At this point was included a copy of Wheeler patent 1,879,863, which was omitted in printing as it is a part of Defendant's Exhibit A, and is printed herein at pages

4-7-27
11-3-30

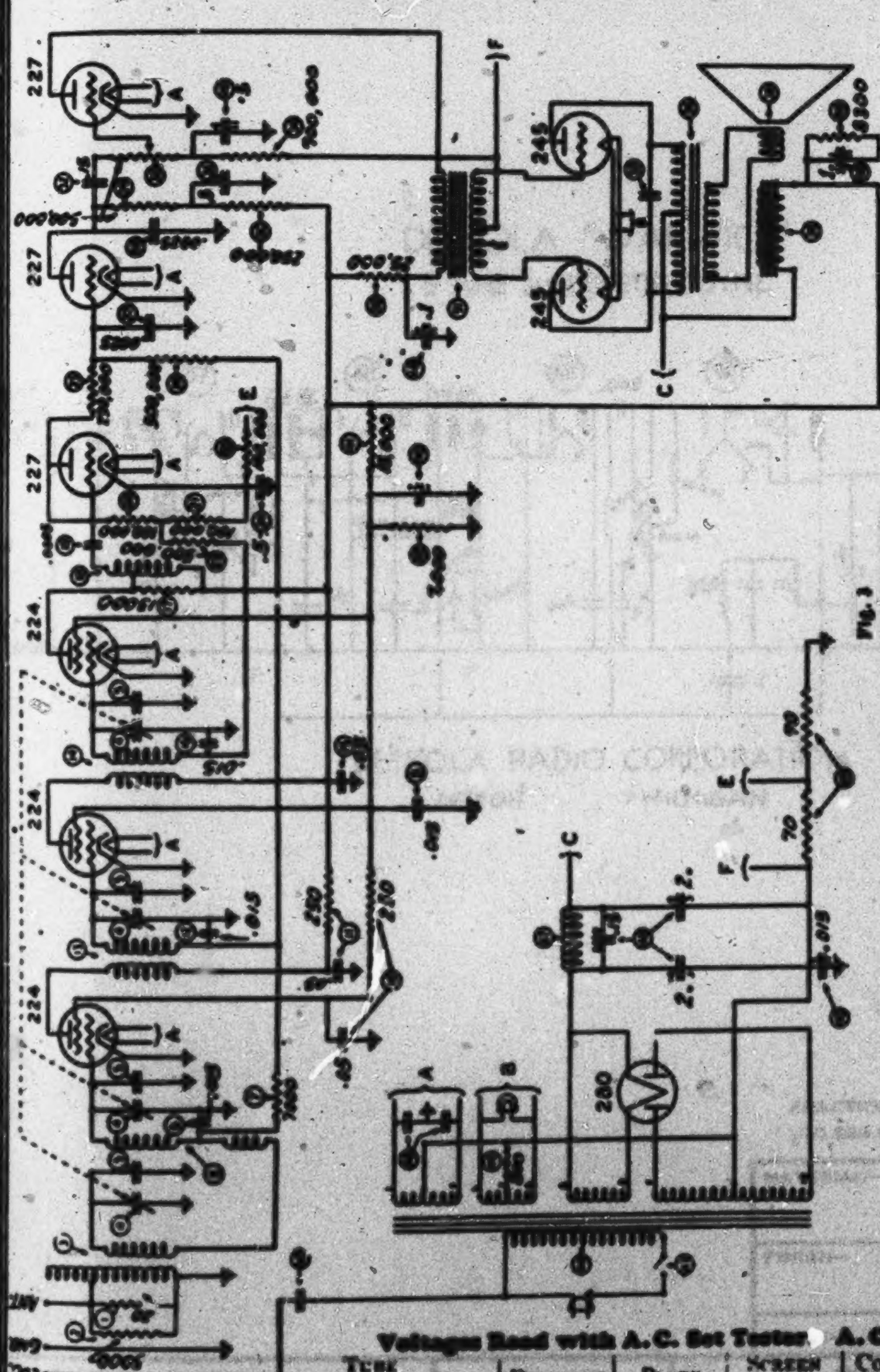
25
6
7/4-32

1930

CONTENTS:

MODEL 96

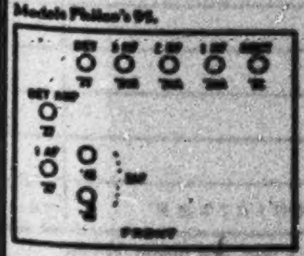
PHILCO RADIO & TELEVISION CORP.



Power Transformer Voltages

Terminals	A.C. Volts	Secondary
3—4	2.67	Heaters of 224 and 227 Tubes
5—6	2.68	Filaments of 245 Tubes
2		Center Tap for 245 Tubes
8—9	5.00	Filament of 280 Tube
7—10	7.50	Plate of 280 Tube
1		Center Tap for 280 Tube
Yellow Wire		Center Tap for 224 and 227 Tubes
Black Wire		Primary
Green Wire		Primary

Models Philco's 96.



Voltages Read with A.C. Set Tester. A.C. Line 125 Volts.

Tube Type	Tube Circuit	Filament Volts	Plate Volts	Screen Grid Volts	Control Grid Volts	Cathode Volts	Plate Milli-Amperes
280	Rectifier	4.5					43/Plate
224	1st R. F.	2.15	155	95	0	5.3	4
224	2d R. F.	2.15	155	95	0	5.3	4
224	3d R. F.	2.15	155	95	0	5.3	4
227	Det.	2.15	0		-.5	.7	0
227	Det. Amp.	2.15	27		-.5	5.5	0
227	1st A. F.	2.15	85		-2.0*	5.5	2.5
245	2d A. F.	2.2	250		41		25
245	2d A. F.	2.2	250		41		25

*This is read with Volume Control off. With it on the reading will be .2 volt.

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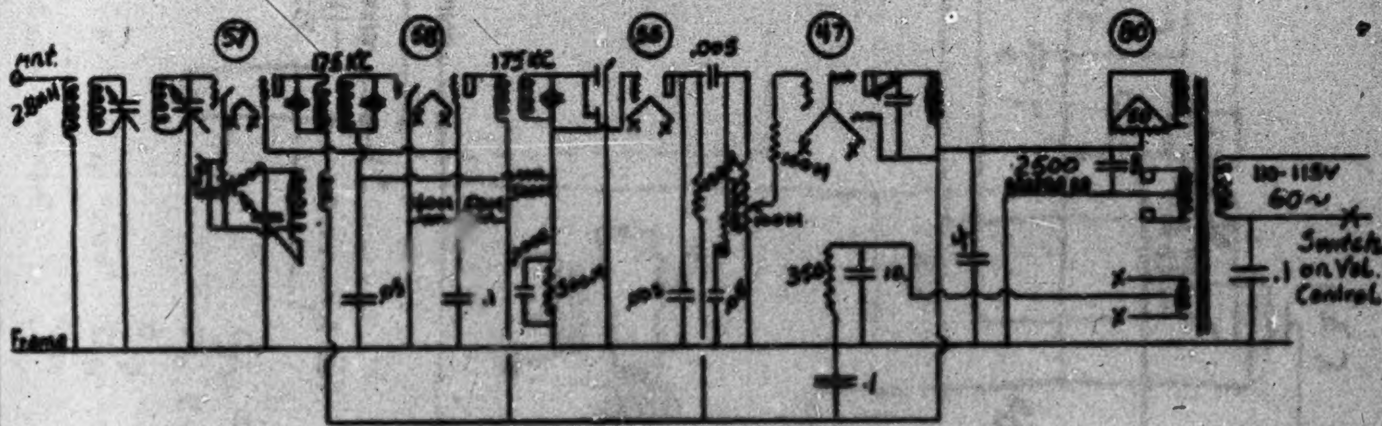
DEFENDANT'S EXHIBIT D

DETROLA "WARWICK"
5 TUBE SUPERHETERODYNE



DETROLA RADIO CORPORATION
DETROIT MICHIGAN

FRACTIONAL DIMENSIONS ±
UNLESS OTHERWISE SPECIFIED.

MATERIAL—

FINISH—

SCALE—

DETROLA RADIO
CORPORATION
DETROIT, MICHIGAN

DRAWN

APPR.

PART No.

D.O. NO.	REVISION	LETTER	MODEL	NO. REQ.
		F		
		E		
		D		
		C		
		B		
		A		

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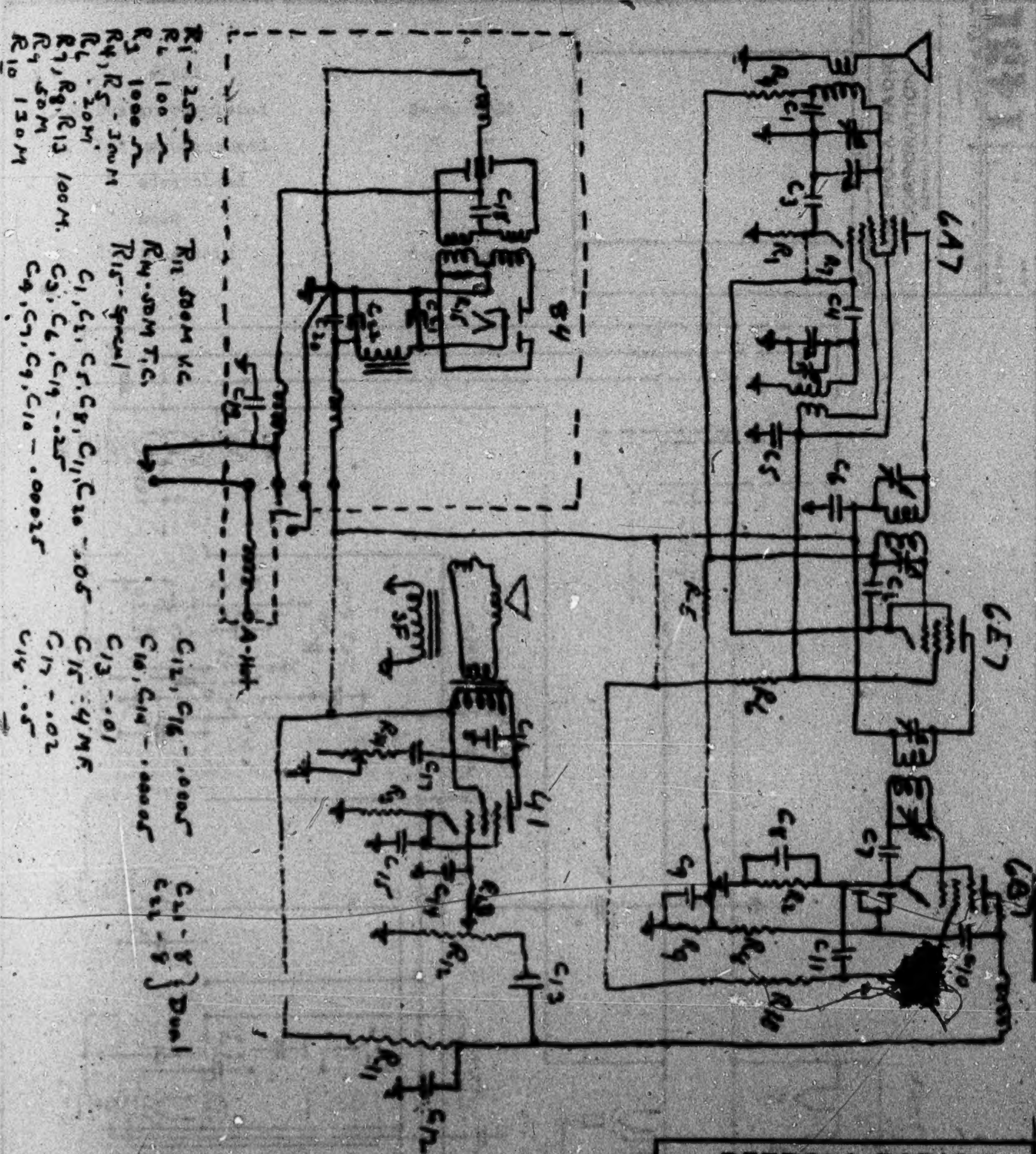
DEFENDANT'S EXHIBIT E



#763 Our Model 1100

(Sears, Roebuck set)

DETROLA RADIO CORPORATION

Detrola Model-1100
S.R. Co. Model-763

A. Design completed - Mar. 1933

B. 1st manufactured - " "

C. " advertised - " "

D. " sold - " "

E. How long sold - 7 months

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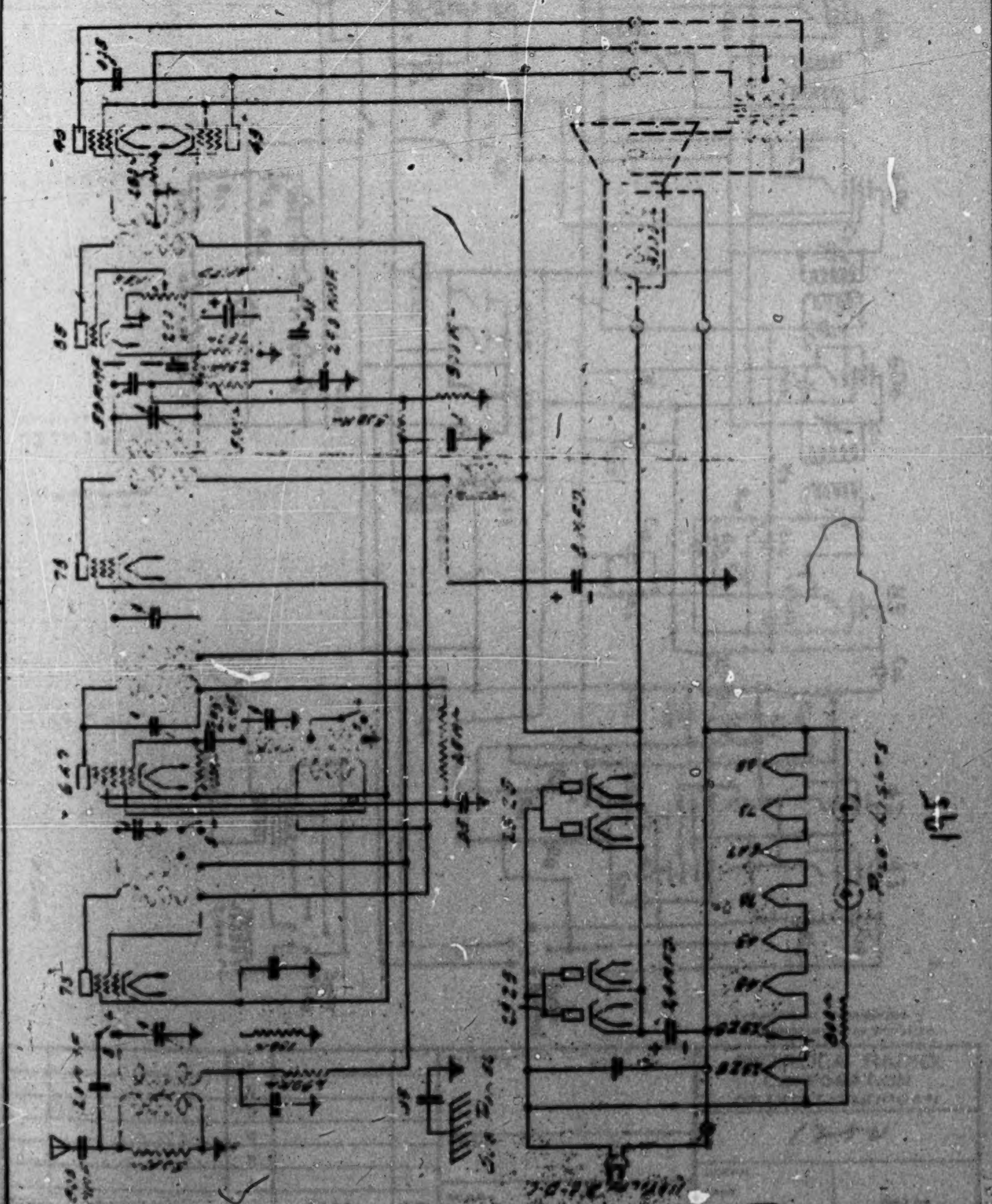
DEFENDANT'S EXHIBIT F

	#1431	#CO	
A.	Design completed	-	Sept. 1933
B.	1st manufactured	-	" "
C.	" advertised	-	" "
D.	" sold	-	" "
E.	How long sold	-	4 months

DETROLA RADIO CORPORATION
DETROIT, MICHIGAN

1431



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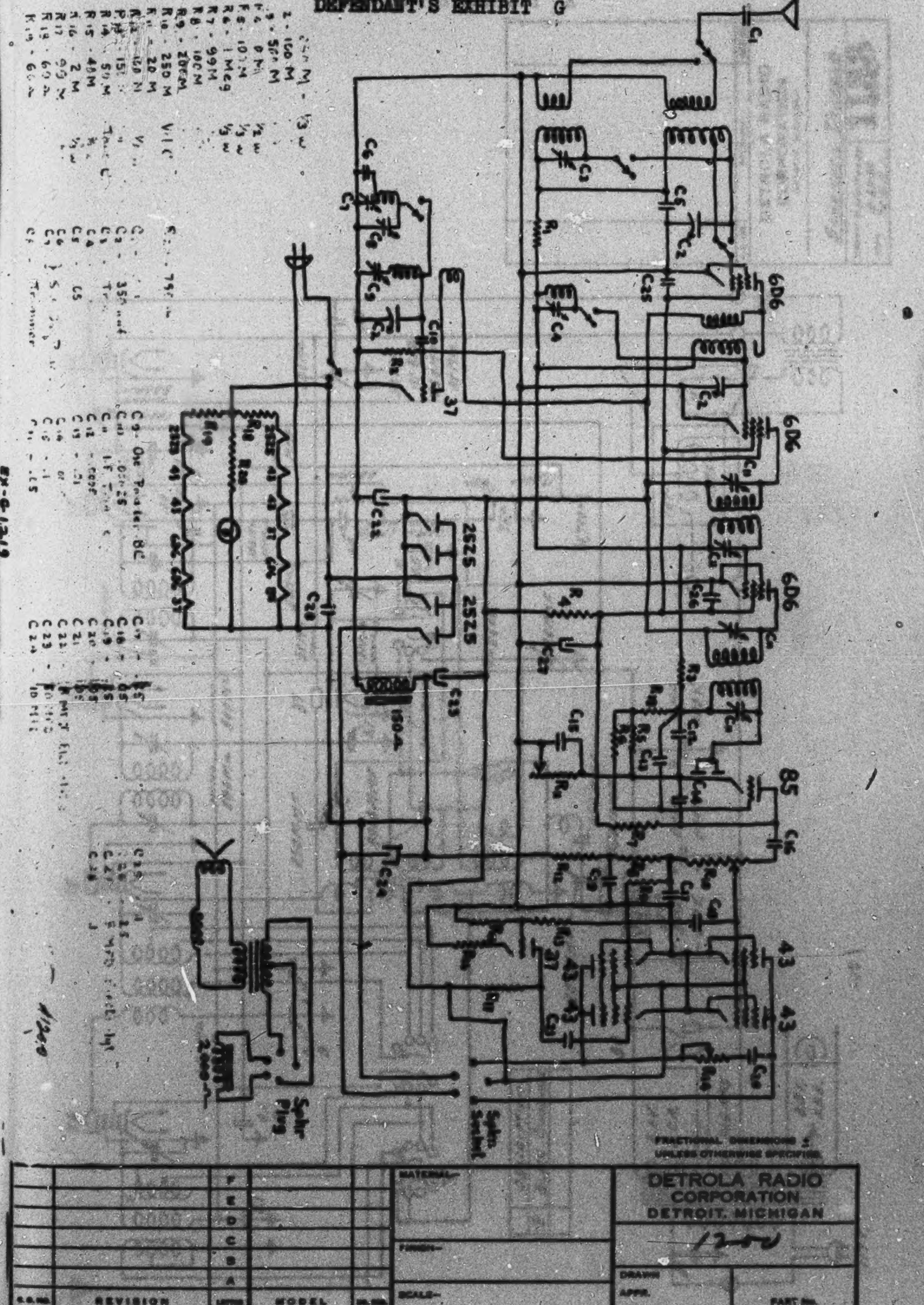
DEFENDANT'S EXHIBIT G



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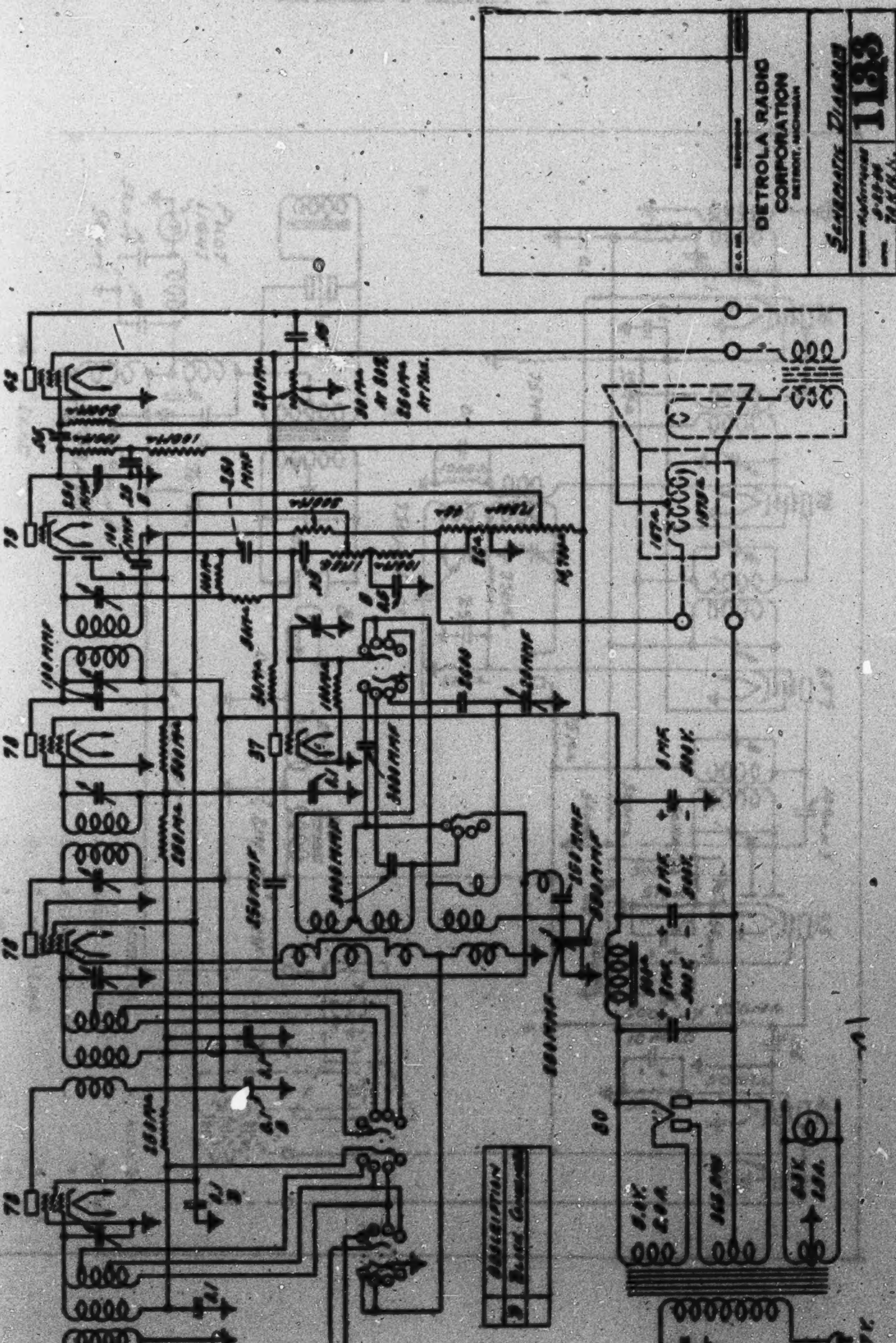
DEFENDANT'S EXHIBIT H



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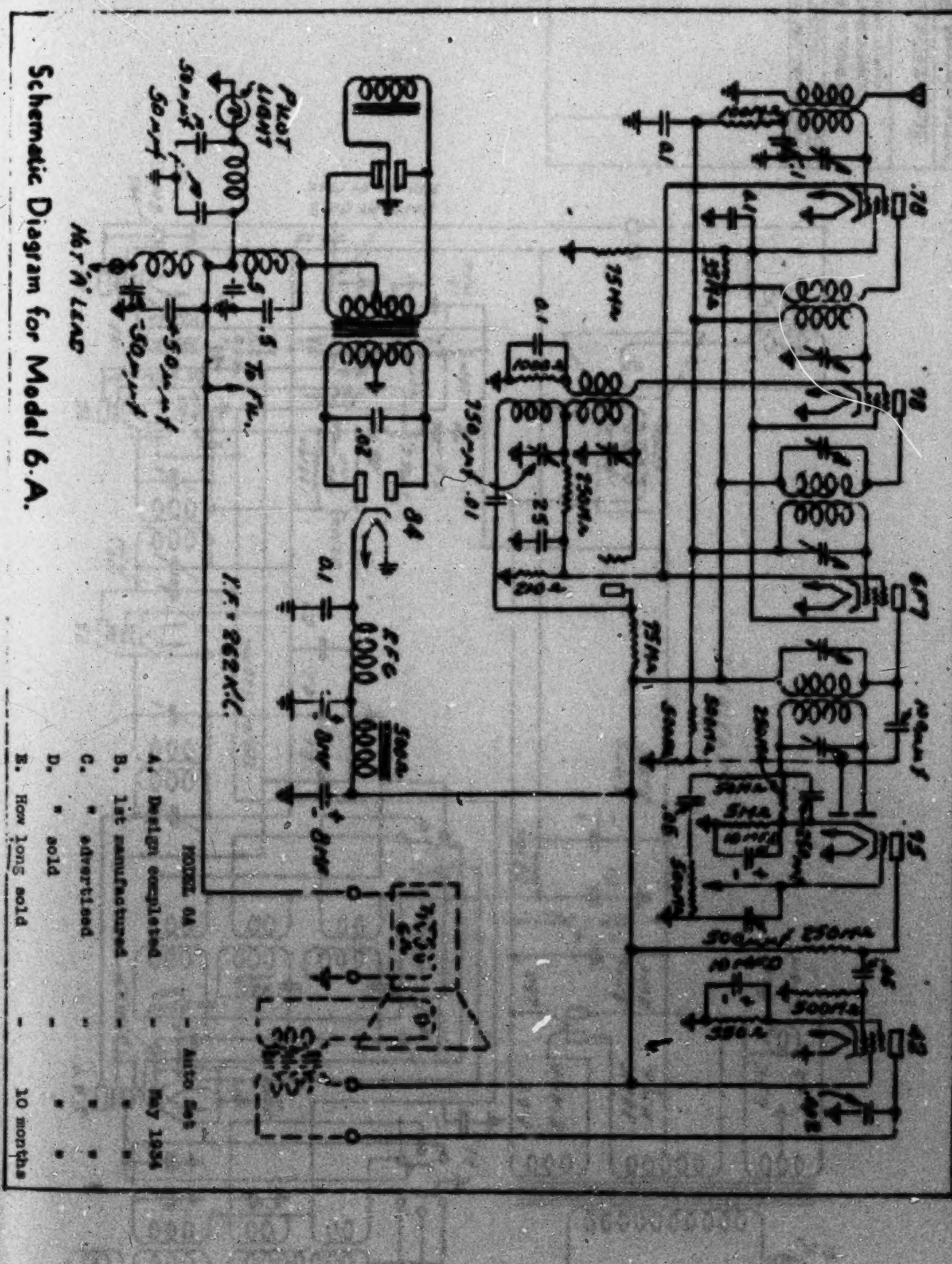
DEFENDANT'S EXHIBIT I



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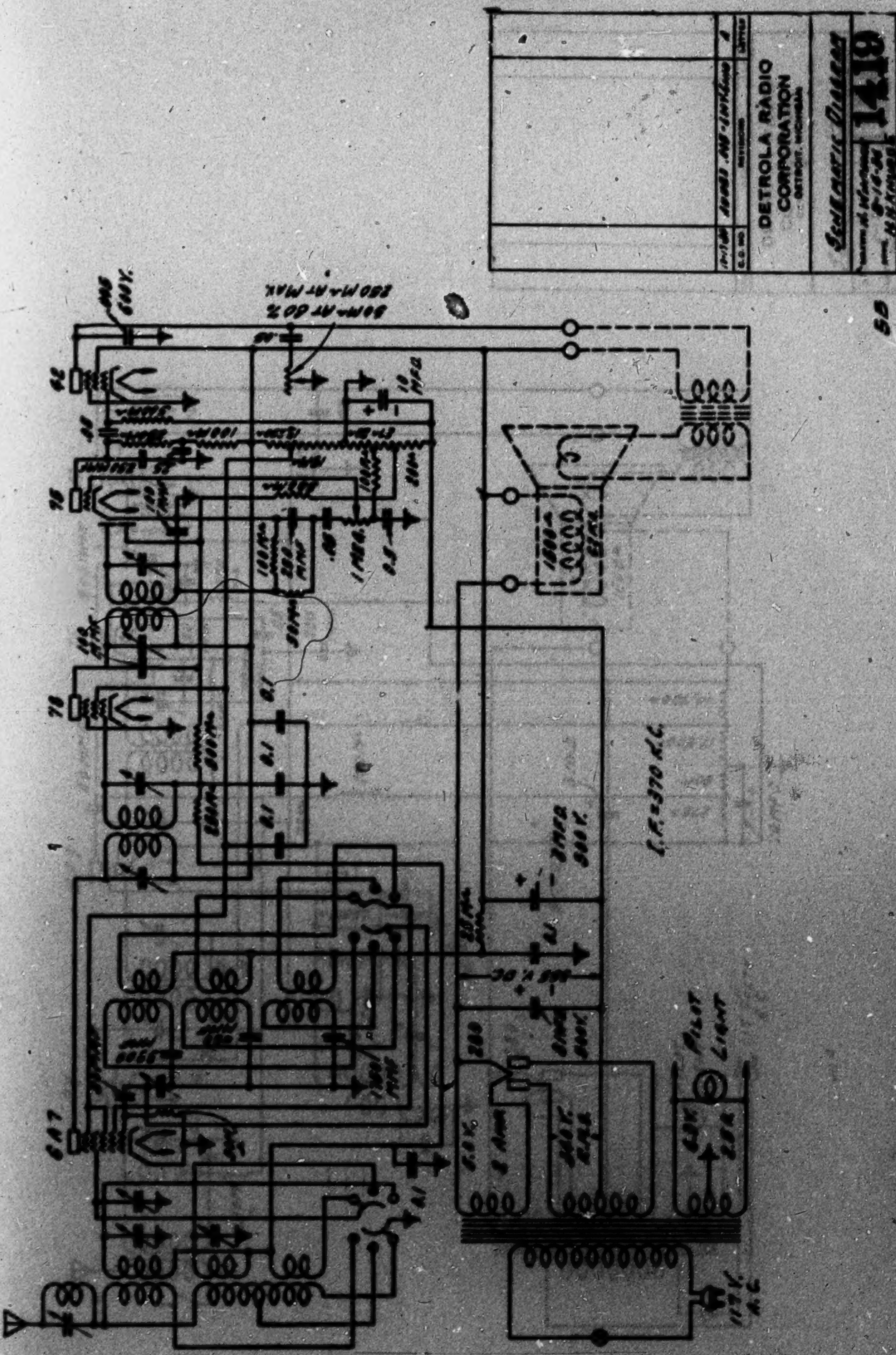
DEFENDANT'S EXHIBIT J



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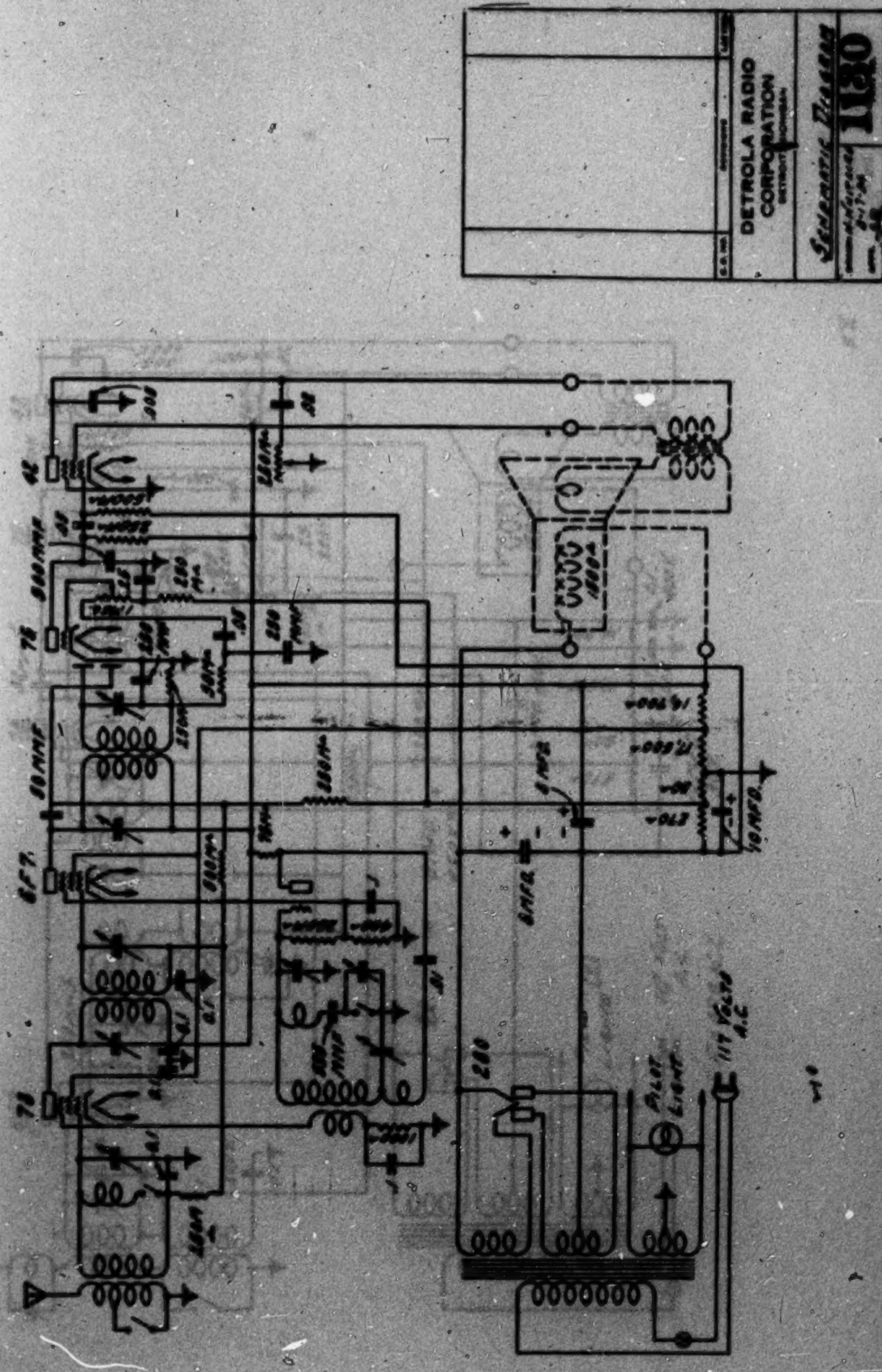
DEFENDANT'S EXHIBIT K



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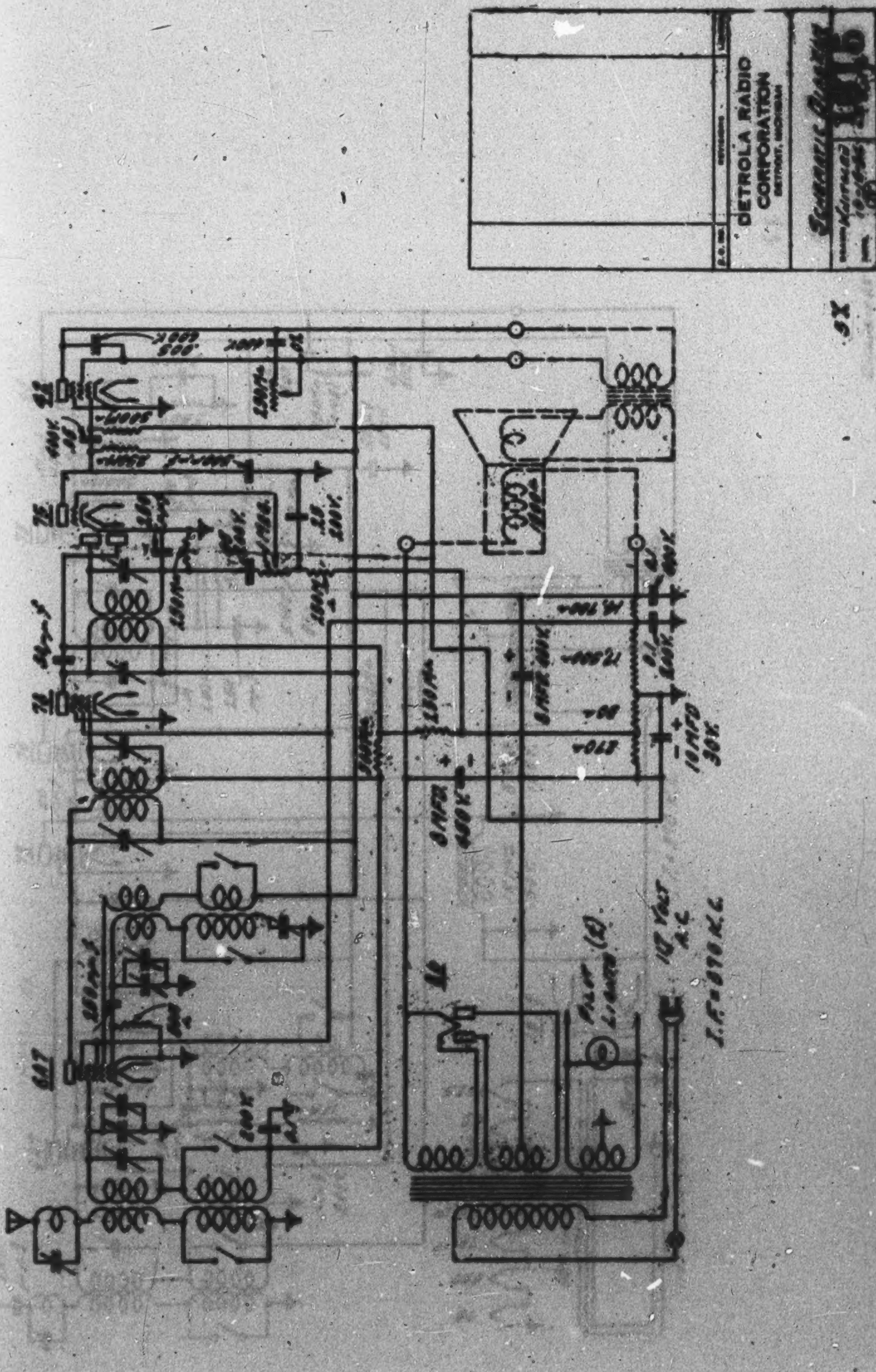
DEFENDANT'S EXHIBIT L



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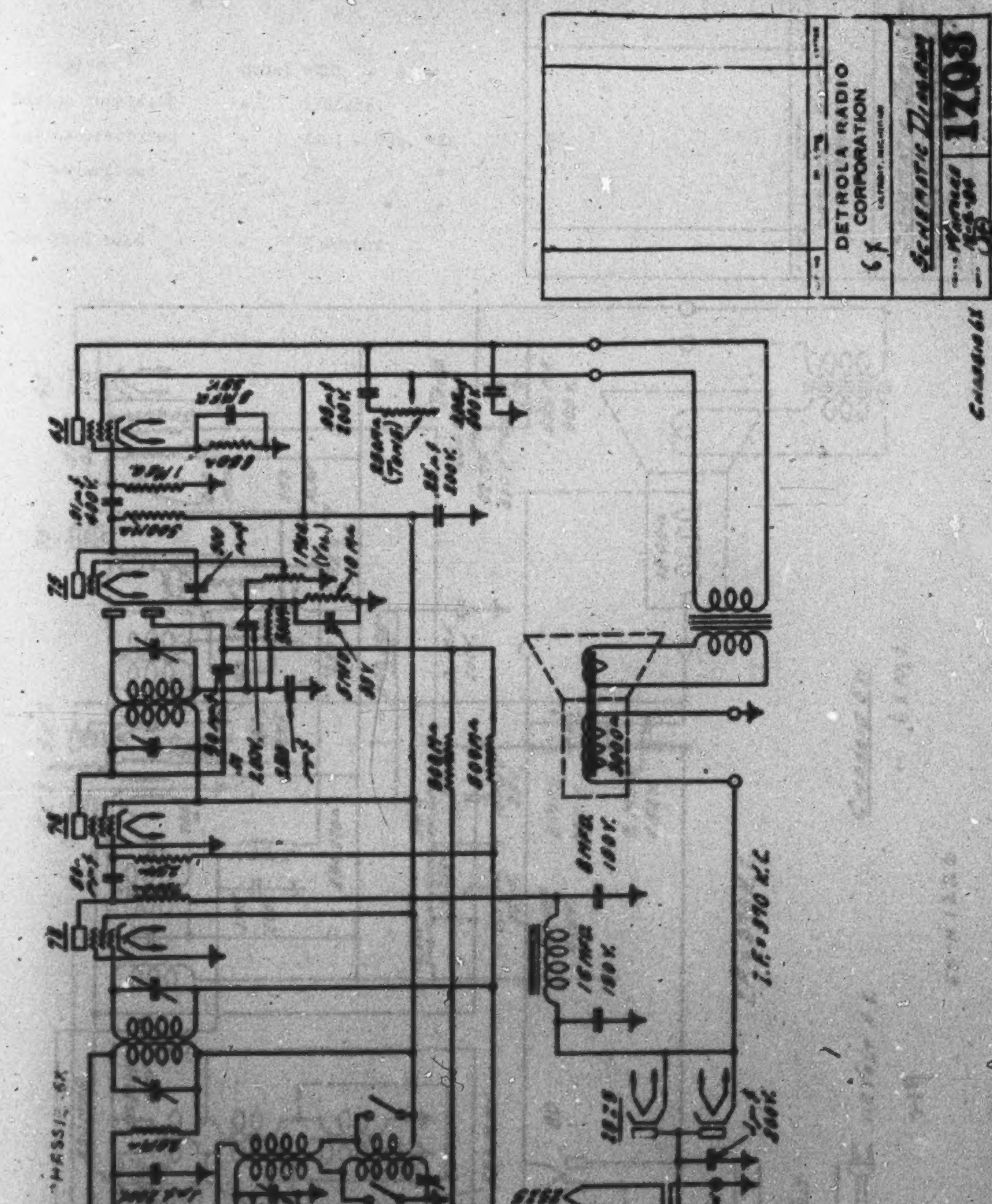
DEFENDANT'S EXHIBIT M



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DEFENDANT'S EXHIBIT N

#1766 Model 6XM1 - & 6W

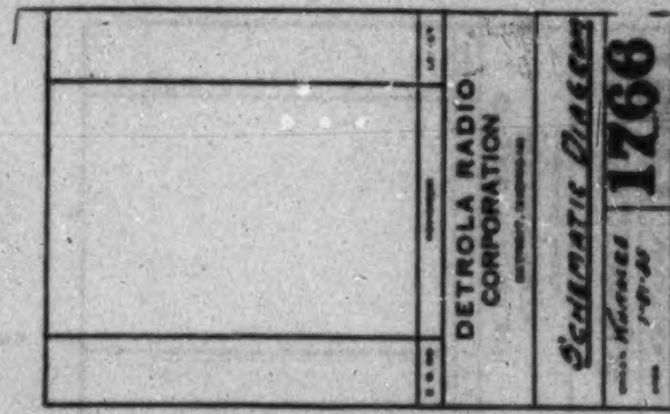
A. Design completed - 1/21/35

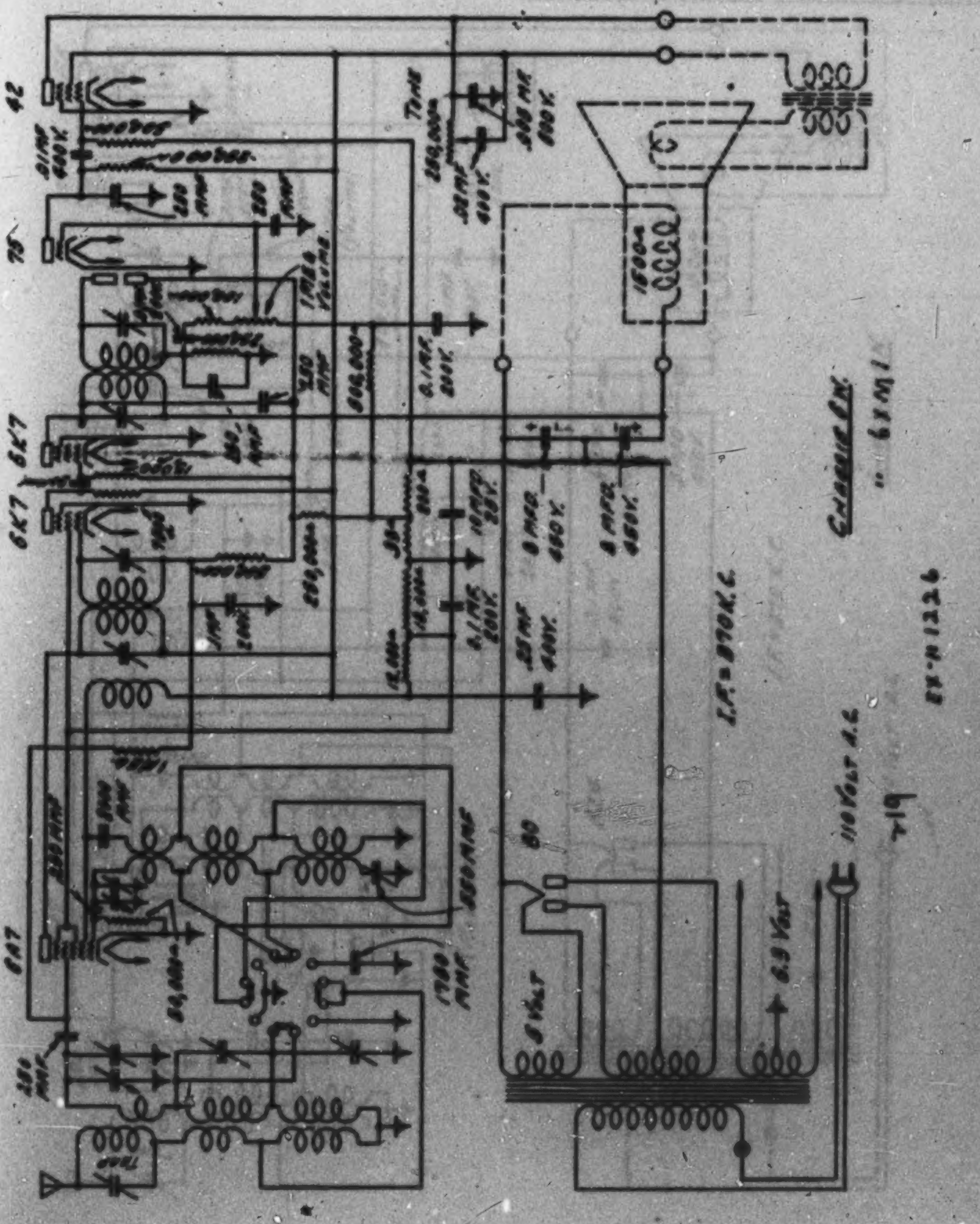
B. 1st manufactured - Jan. - Feb. '35

C. " advertised - " " "

D. " sold - " " "

E. How long sold - 9 months





414

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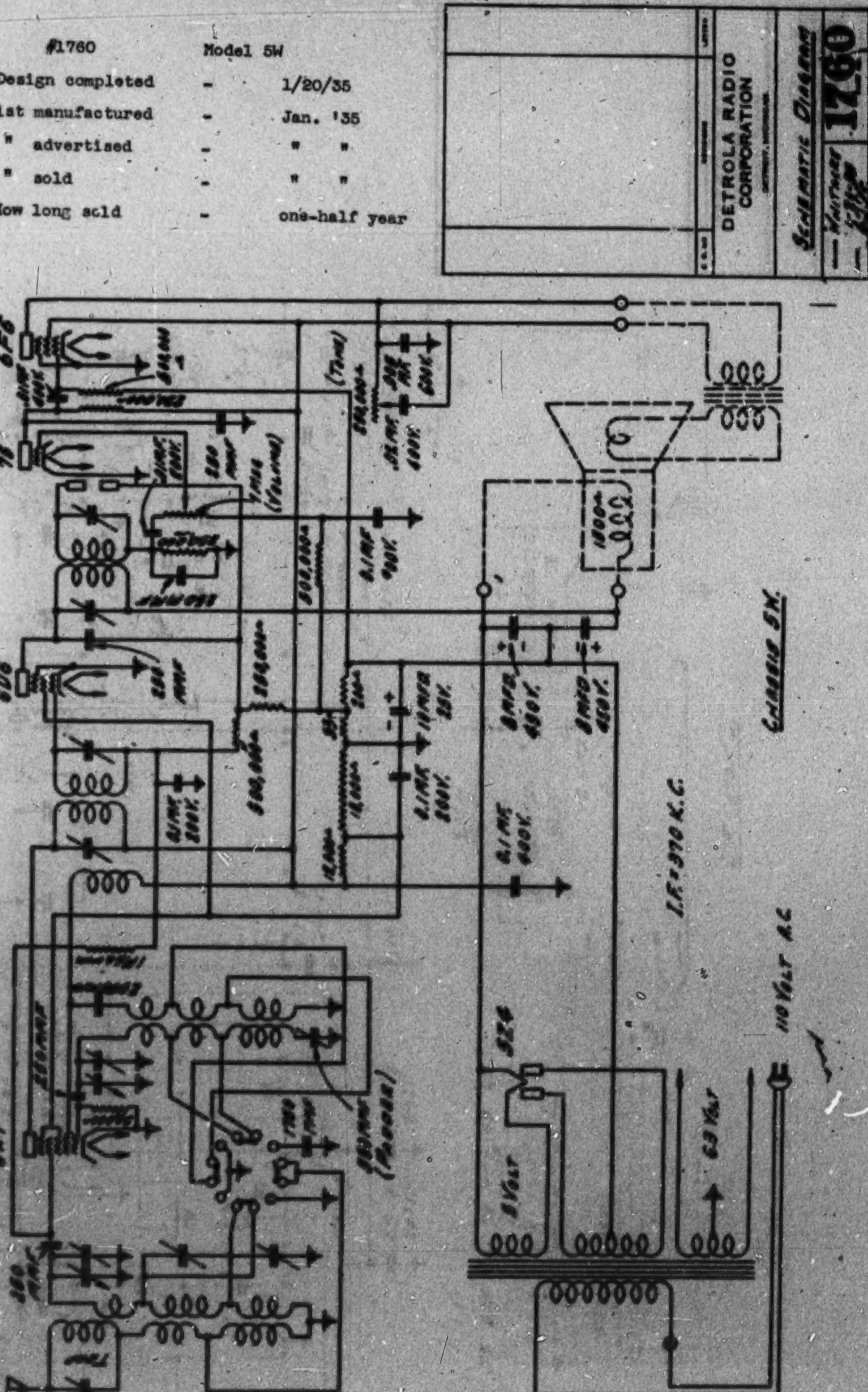
DEFENDANT'S EXHIBIT O

#1760	Model 5W		
A.	Design completed	-	1/20/35
B.	1st manufactured	-	Jan. '35
C.	" advertised	-	" "
D.	" sold	-	" "
E.	How long sold	-	one-half year



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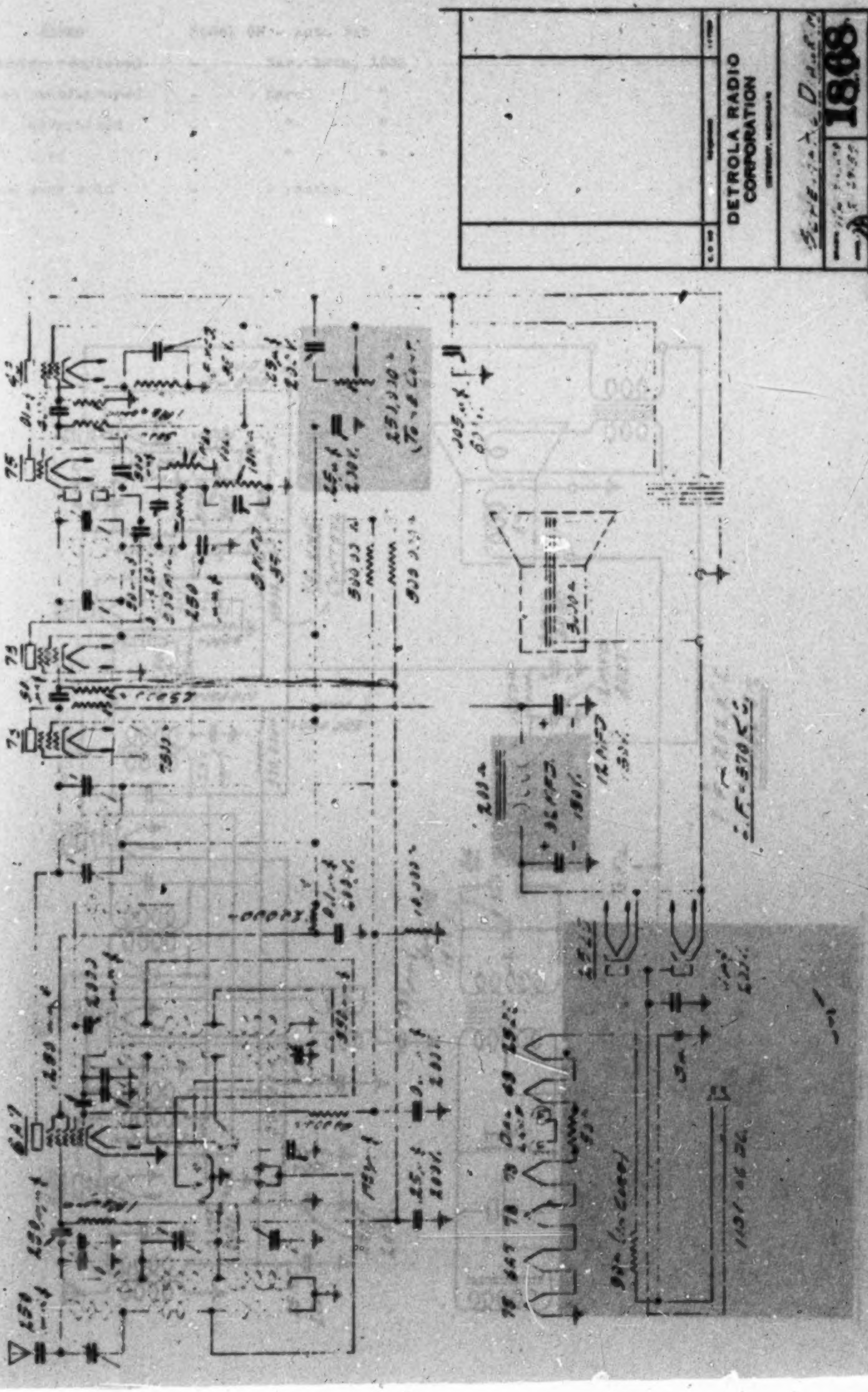
DEFENDANT'S EXHIBIT P



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DEFENDANT'S EXHIBIT Q

#1944 Model 6M - Auto Set

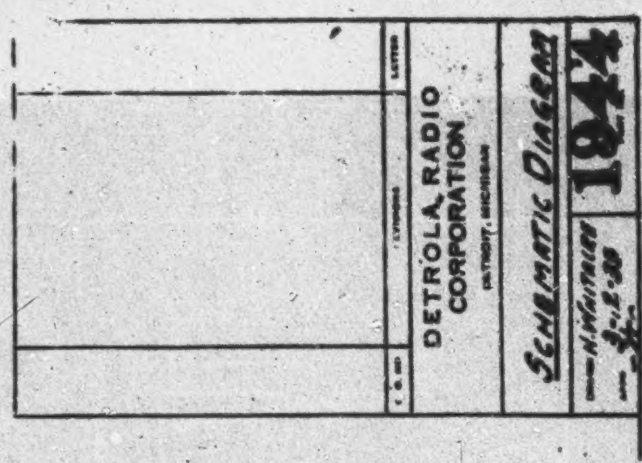
A. Design completed - Mar. 12th, 1935

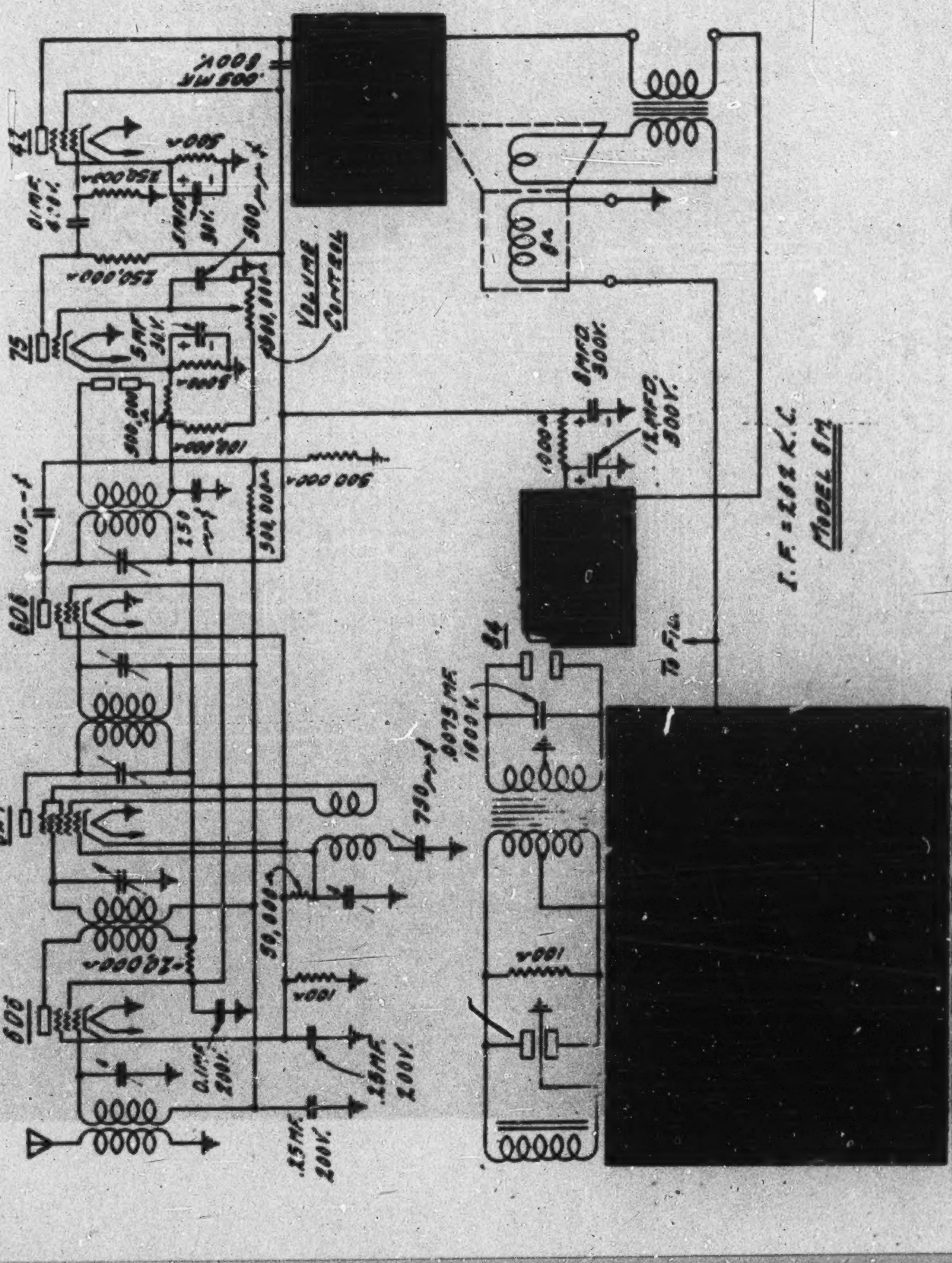
B. 1st manufactured - March "

C. " advertised - " "

D. " sold - " "

E. How long sold - 9 months





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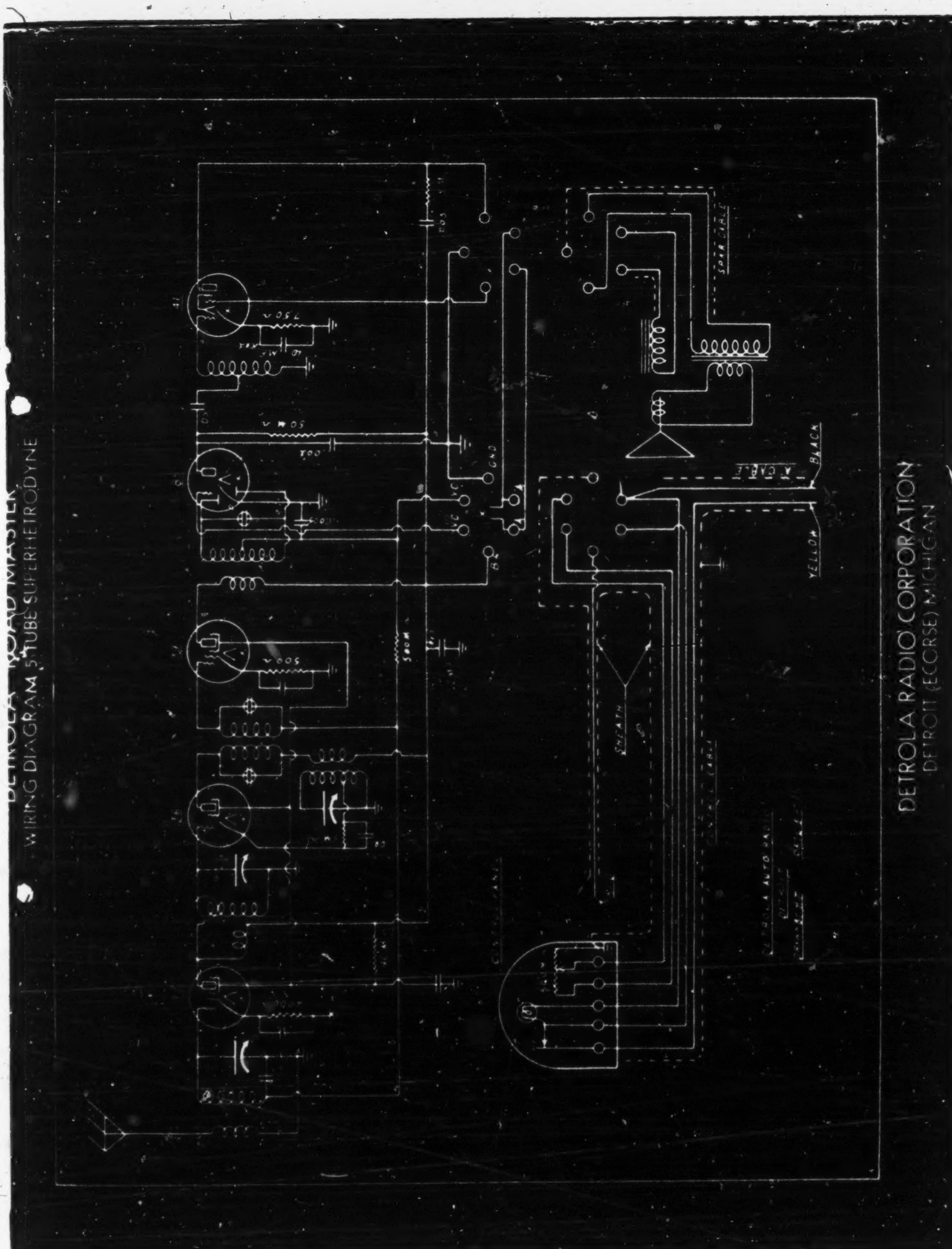

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DEFENDANT'S EXHIBIT T

* Patents cited in Wheeler Reissue Patent No. 19,744

X Patents cited in the original Wheeler Patent No. 1, 879,863

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Friis	X	1,675,848 ✓	11.
Heising	*	1,687,245 ✓	12.
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Green		1,738,000	17.
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Publications

May 15, 1923. 1,455,768

J. SLEPIAN

WIRELESS RECEIVING SYSTEM

Filed Jan. 20, 1922

Fig.1.

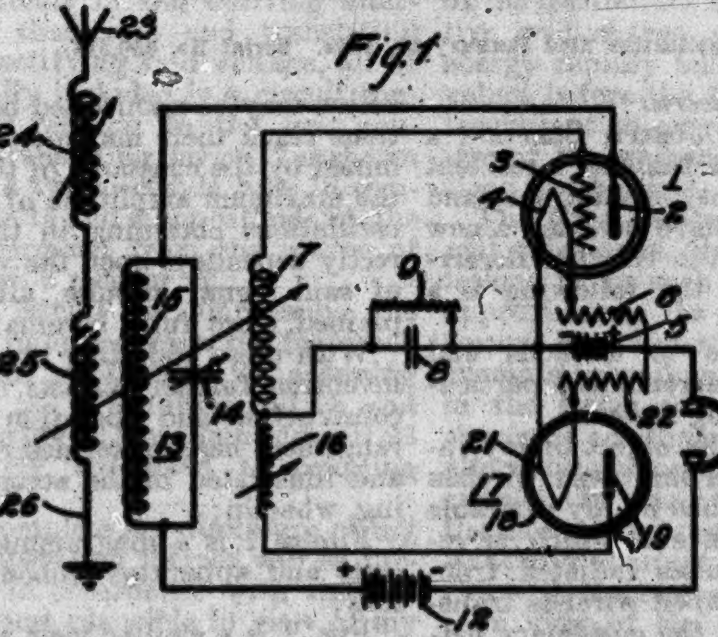


Fig.2.

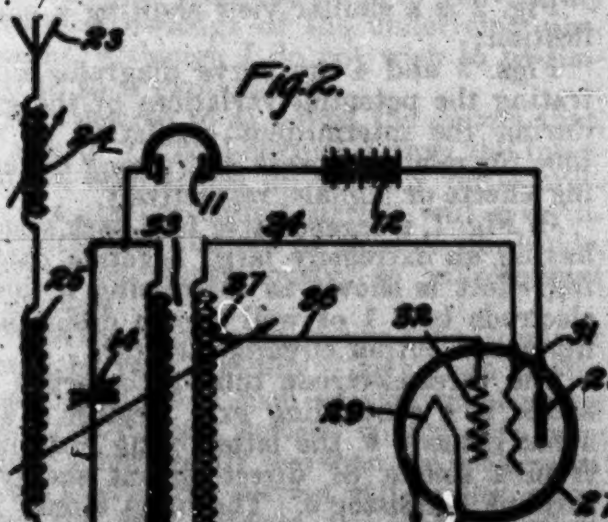


Fig.3.

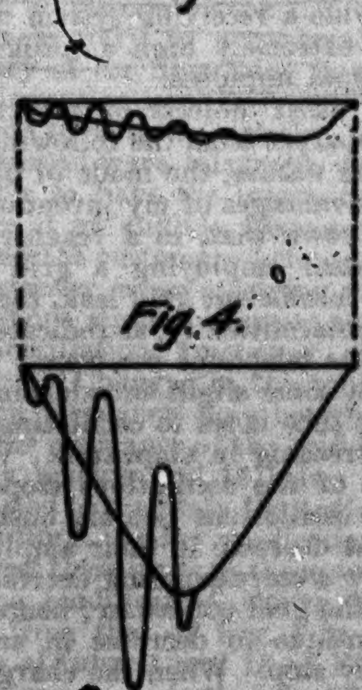


Fig.4.

WITNESSES:

A. L. Alfing

H. L. Godfrey

INVENTOR

Joseph Slepian

BY

Chesley Glass

ATTORNEY

Patented May 15, 1923. 1,455,768

UNITED STATES PATENT OFFICE.

JOSEPH SLEPIAN, OF SWISSVALE, PENNSYLVANIA, ASSIGNOR TO WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY, A CORPORATION OF PENNSYLVANIA.

WIRELESS RECEIVING SYSTEM.

Application filed January 20, 1922. Serial No. 530,615.

To all whom it may concern:

Be it known that I, Joseph Slepian, a citizen of the United States, and a resident of Swissvale, in the county of Allegheny and State of Pennsylvania, have invented a new and useful Improvement in Wireless Receiving Systems, of which the following is a specification.

My invention relates to methods and means for amplifying currents and particularly to wireless receiving systems.

In its broad aspect, the object of my invention is to provide an improved wireless receiving system which has highly desirable operating characteristics and which is responsive to signal impulses radiated from either damped or undamped wireless transmission systems without the customary heterodyning step.

More specifically, one object of my invention is to provide a receiving system which admits of an extremely high amplification of received signal impulses.

These and other objects of my invention will be apparent from the following description of the nature, the mode of operation and the advantages of my invention.

It is well known that, in a regenerative feed-back system employing a grid condenser having insufficient grid leak, the system oscillates intermittently, as indicated by a howling in the telephone receivers. That is to say, upon some slight unbalancing of the system, the tube is set to oscillating, the oscillations increasing in amplitude. When the amplitude of the oscillations stops increasing, the oscillations become unstable, since any slight decrease in their amplitude fails to produce a corresponding decrease in the charge in the grid condenser; hence the oscillations continue to decrease in amplitude and finally stop. When the charge on the grid condenser has decreased to a sufficiently low value, as determined by the constants of the system, the oscillations again build up, as before, and the blocking action is repeated. It will be noted that the oscillations must build up to approximately the maximum limits of the tube before the blocking action becomes effective.

I have found that, by increasing the charge on the grid to values higher than the peak value of the alternating grid potential, in accordance with the varying intensity of a signal impulse to be detected, the blocking action may be manifested before the oscillations reach their maximum value, as determined by the constants of the tube, and that the maximum amplitude of the intermittent oscillations obtaining in the system is directly dependent upon the varying intensity of said signal impulse, all as will be explained more fully hereinafter.

With these and other objects in view, my invention further consists in the details of construction and operation and circuit arrangement hereinafter described and claimed and illustrated in the accompanying drawing, wherein:

Figure 1 is a diagrammatic view of circuits and apparatus embodying my invention;

Fig. 2 is a similar view showing a modification;

Figs. 3 and 4 are curve diagrams illustrating the potential variations of the grid during the intermittent oscillation of the tube for relatively weak and strong disturbing effects or signals, respectively.

In Fig. 1, a regenerative feed-back system having an extremely large negative damping effect is shown as comprising a three-electrode tube 1 of well known design and input and output circuits therefor.

The three-electrode tube 1 comprises an anode 2, a controlling grid member 3 and a hot cathode 4, the latter being energized from a source of direct-current energy 5 through a resistor 6. The input circuit includes a coupling coil 7 and a shunt-connected grid condenser 8 and adjustable grid leak 9. The grid leak is so adjusted as to cause said feed-back system to oscillate intermittently at a predetermined frequency upon the receipt of an initial impulse, as by a received signal impulse.

The output or plate-filament circuit includes a translating device shown as a telephone receiver 11, a source of direct-current energy 12 and a tuned circuit 13. The tuned circuit 13 comprises a condenser 14 and a coupling coil 15 connected in shunt relation, the latter being inductively coupled to the coupling coil 7 which is included in the grid-filament circuit. The feed-back coupling between the coils 15 and 7 is so adjusted as to provide a regenerative system having an extremely large negative-resistance effect.

An auxiliary grid-biasing means is provided for increasing the negative charges on

the grid condenser 8 to values greater than the peak-value of the alternating-grid potential in accordance with the varying intensity of the disturbing impulses tending to unbalance the feed-back system, and comprises a coupling coil 16 inductively coupled to the tuned circuit 13 and deriving alternating voltage therefrom and translating means 17 for rectifying said voltage, all of which are serially included in a circuit connected in shunt relation to the grid condenser 8. The translating device 17 is shown in the form of a two-electrode tube 18 comprising an anode 19 and a hot cathode 21, the latter being energized from the source of energy 5 through a resistor 22.

An antenna circuit for impressing the received signal impulses upon the feed-back system comprises an antenna 23, a tuning inductance coil 24, a coupling coil 25 and a ground conductor 26, the coupling coil 25 being operatively connected to coupling coils 15, 16 and 7.

In order to complete the disclosure of my invention, the operation thereof will be further explained in accordance with theories which appear most plausible in view of my present knowledge of the underlying phenomena, although I do not wish to be limited to such explanation.

It is desired to so adjust the system that, if a certain signal-current brings the intermittent oscillations up to their full amplitude, a smaller signal-current will give intermittent oscillations of smaller amplitude, and so on, continuously, to infinitesimal amplitude.

With the usual regenerative tube circuit, it would be very difficult, if at all practically possible, to make such adjustment, because the direct-current voltage on the grid condenser is necessarily less than the peak value of the alternating-current voltage impressed upon the grid. Hence, the blocking effect cannot manifest itself until the oscillations have built up to a steady value determined by the limits of the tube.

In the circuit shown in Fig. 1, however, the auxiliary biasing rectifier 18 and voltage-source 16 cause the grid condenser to charge up to a higher direct-current voltage than the peak of the alternating-current grid voltage. By reason of the feed-back coupling connection of the biasing coil 16, the amount of increase in the charge on the grid-condenser 8, and hence the blocking tendency of the system, is dependent upon the magnitude of the oscillations which are initially determined by the magnitude of the disturbing impulse or signal-current.

Thus, when a small signal-current is received, the oscillations may build up relatively slowly and nearly reach a steady state before the system becomes unstable, whereupon the oscillations are rapidly damped, as indicated in Fig. 3. When the grid charge has decreased to a sufficiently low value, if the disturbing effect is still present, the cycle is repeated.

However, when strong signal-current is impressed upon the system, the amplitude of the oscillations and, as a result, the negative grid charge, as well as the feed-back energy rapidly build up to relatively large values before the feed-back energy becomes insufficient to overcome the positive damping of the system, whereupon the oscillations are blocked, as illustrated in Fig. 4.

The time necessary for the building up and subsequent blocking of the tube oscillations is, in each of the cases illustrated, approximately the same, inasmuch as, in the former case, lower alternating voltages and currents prevail in the plate circuit, while, in the latter case, the increased negative charge is accompanied by greatly increased alternating voltages and currents in the plate circuit. In other words, the frequency of the intermittent oscillations may remain substantially constant while the amplitude varies with the intensity of the signal-current.

In view of the foregoing description, it will be observed that the effect of the auxiliary biasing means is to cause the maximum amplitude of the intermittent oscillations to vary in accordance with the intensity of the disturbing impulses and that my invention is directly applicable to the detection of wireless signals. When receiving undamped-wave telegraph signals, it is desirable to have the intermittent-oscillations occur at an audible frequency, hence eliminating the customary heterodyning step.

However, when receiving continuous-wave telephone signals, a super-audible intermittent-oscillation frequency should be employed. Changes in the intermittent oscillatory frequency may be effected by varying the resistance of the grid leak 9, the auxiliary biasing coil 16 being simultaneously adjusted to maintain the optimum operating conditions. Other applications will readily suggest themselves to those versed in the art.

The modification shown in Fig. 2 differs from that of Fig. 1 in that the functions of tubes 1 and 18 of Fig. 1 have been combined in a single tube 27 employing an anode 28, a hot cathode 29 and a pair of grid members 31 and 32. The grid member 31, which corresponds to the anode 19 of Fig. 1, is either made more remote from the hot cathode 29 than the grid 32, or both, in order to reduce the effect of the grid 31 upon the plate-filament circuit.

The system is further modified by replacing coils 7 and 16 of Fig. 1 with a single coil 33, opposite terminals of which are connected, by conductors 34 and 35, to the grid 31 and the hot cathode 29, respectively. The shunt connected grid condenser 8 and leak

9 are included in series-circuit relation to the conductor 35. The grid 32 is connected, by a conductor 36, to an adjustable tap-point 37 on the coil 33. The grid biasing circuit now includes the coil 33, the conductor 34, the grid 31 and the conductor 35. The operation of this system is similar to that of Fig. 1.

While I have shown but two embodiments of my invention, for the purpose of describing the same and illustrating its principles, it is capable of various changes and modifications without departing from the spirit thereof, and I desire, therefore, that only such limitations shall be placed thereon as are demanded by the prior art or are specifically set forth in the appended claims.

I claim as my invention:—

1. An electrical system having a high negative damping effect tending to cause said system to function as an oscillation generator, means tending to periodically introduce a blocking effect, means associated with said system carrying currents to be detected and means for modulating said blocking effect in accordance with the intensity of said currents.

2. In an electrical system, a regenerative feed-back system adapted to generate sustained oscillating currents, means tending to cause said system to oscillate intermittently, means carrying impulses to be detected and means for controlling the blocking of said system in accordance with the amplitude of said impulses.

3. In an electrical system, a feed-back circuit having a high negative damping effect tending to cause said system to function as an oscillation generator, means tending to periodically introduce a blocking effect, whereby said system oscillates intermittently, means carrying currents to be detected and means inherently modulating the intensity of the blocking effect in accordance with the amplitude of said currents.

4. In an electrical system, a regenerative feed-back system adapted to generate sustained oscillatory currents, means tending to cause said system to oscillate intermittently, means carrying currents to be detected and means associated with said former means and with said system for controlling the amplitude of said intermittent oscillations in accordance with the intensity of said currents to be detected.

5. In an electrical system, a regenerative feed-back system adapted to generate oscillatory currents, means for causing said system to oscillate intermittently, means carrying currents to be detected and means inherently effective to control the maximum amplitude of said intermittent oscillatory currents in accordance with the intensity of said currents to be detected.

6. An electrical system comprising an unbalanced regenerative feed-back system, means for unbalancing said system, whereby the same may function as an oscillation generator, means for causing said system to oscillate intermittently and means associated with said system, whereby said intermittent oscillations are caused substantially to cease upon the removal of said unbalancing means.

7. An electrical system comprising a regenerative system having a large negative damping factor, a circuit carrying variable currents operatively associated therewith, said currents initially tending to start said regenerative system functioning as an oscillation generator, means for causing the oscillations generated thereby to occur intermittently according to a predetermined frequency and means cooperating with said last-mentioned means, whereby said regenerative system is rendered ineffective upon the elimination of said currents.

8. In an electrical system, a regenerative feed-back system adapted to generate sustained oscillatory currents, means having the effect of a leaky condenser associated therewith for causing said system to oscillate intermittently and auxiliary means for increasing the effect of said first-mentioned means.

9. In a regenerative feed-back system, a tube containing a controlling member, input and output circuits therefor so adjusted as to cause said tube to function as an oscillator, means for causing said controlling member to assume a charge comparable to the normal maximum alternating voltage impressed thereon during the oscillatory periods of said tube and means for greatly increasing said charge during such periods.

10. In a regenerative feed-back system, a tube containing a grid member, input and output circuits therefor, said circuits being so adjusted as to cause said tube to function as an oscillator, means having the effect of a leaky condenser associated with said grid member for causing the same to assume a negative charge comparable to the peak value of the normal alternating grid voltage effective during regenerative action and current-responsive means for increasing said grid-charge to values higher than said peak value.

11. In a regenerative feed-back system, a vacuum-tube device containing a control-member, input and output circuits associated with said device, said circuits being so adjusted as to cause said tube to function as an oscillation generator, a shunt-connected capacitive reactance device and grid-leak device serially included in said input circuit, whereby charges are caused to form on said member comparable to the peak value of the alternating voltage impressed thereon, and means for increasing said grid-charge to values higher than said peak values.

12. In a regenerative feed-back system, a

vacuum-tube device containing a control-member, input and output circuits associated with said device, said circuits being so adjusted as to cause said tube to function as an oscillation generator, means having the effect of a leaky condenser included in said input circuit for causing said member to assume a negative charge comparable to the peak value of the alternating voltage impressed thereon during regenerative action, means for deriving alternating-current energy from said system, means for translating said energy into unidirectional-current energy and circuit connections for impressing said latter energy upon said first-mentioned means.

13. In a regenerative feed-back system, a vacuum-tube device containing a control-member, input and output circuits associated with said device, said circuits being so adjusted as to cause said tube to function as an oscillation generator, means having the effect of a leaky condenser included in said input circuit for causing said member to assume a negative charge comparable to the peak value of the alternating voltage impressed thereon during regenerative action, means deriving alternating-current energy from said system, and a symmetrically conducting path for translating said energy into unidirectional impulses and circuit connections for impressing said impulses upon said first-mentioned means, whereby said grid-charge may be increased to values higher than said peak value.

14. The combination with an amplifier having input and output circuits, of a source of energy therefor, feed-back means associated therewith in such manner as to produce oscillations which are inherently blocked at periodical intervals and means responsive to variations in the amplitude of currents in said input circuit for causing substantially proportionate variations in the amplitude of said oscillations without materially changing the frequency of interruption thereof.

15. The combination, with an amplifier having input and output circuits, of a source of energy therefor, feed-back means associated therewith in such manner as to produce oscillations which are inherently blocked at periodic intervals and means operative upon the amplitude of said oscillations to a greater degree than upon the intermittent frequency thereof for modulating said oscillations in substantial accordance with the current-strength in said input circuit.

16. The combination, with an oscillation-generator system including an electron-tube having a controlling grid member, of means tending to cause static charges to build up on said grid member upon the generation of oscillations, means tending to dissipate said charges, the constants of the system being so arranged that oscillations are generated and intermittently blocked by the accumulation of said charges, an input circuit operatively associated with said system and carrying oscillatory currents to be amplified and means for causing an increase in the rate of increase of said charges in response to the amplitude of said currents.

17. The combination, with a source of variable oscillatory currents of substantially constant frequency, of an oscillation-generator system of substantially the same frequency coupled thereto, said oscillation-generator system including an electron-tube having coupled output and input circuits, said input circuit including means performing the functions of a grid-condenser and grid-leak, the constants of said system being adjusted to produce oscillations which are inherently blocked at periodic intervals, and auxiliary means responsive to said variable oscillatory currents for impressing unidirectional electromotive force upon said grid-condenser means in such manner as to increase the rate of accumulation of charges thereupon.

18. The combination with a source of variable oscillatory currents of substantially constant frequency, of an oscillation-generator system of substantially the same frequency coupled thereto, said oscillation-generator system including an electron-tube having an anode, a cathode, and two grids, one of said grids operating as a controlling means for the anode current, means having the effect of the grid-condenser with said grid, the other of said grids being so constructed and arranged as to have a relatively slight effect upon said anode-current, and current-responsive means for imposing a unidirectional potential upon said last-mentioned grid in such manner as to increase the charge built upon said grid-condenser means.

19. The method of amplifying currents which consists in causing said currents to control the operation of an oscillation-generator system including an electron-tube having a grid and means for performing the functions of a grid-condenser and grid-leak, adjusting the constants of said system in such manner as to cause the oscillations to be intermittently blocked by the accumulation of charges on said grid-condenser means and causing auxiliary unidirectional potentials to be impressed upon said grid-condenser means in substantial accordance with the amplitude variations in the currents to be amplified.

In testimony whereof, I have hereunto subscribed my name this 4th day of January, 1922.

JOSEPH SLEPIAN.

Certificate of Correction.

It is hereby certified that in Letters Patent No. 1,455,768, granted May 15, 1923, upon the application of Joseph Slepian, of Swissvale, Pennsylvania, for an improvement in "Wireless Receiving Systems," an error appears in the printed specification requiring correction as follows: Page 4, lines 29 and 30, claim 13, for the words "and a symmetrically" read *an asymmetrically;* and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 19th day of June, A. D., 1923.

[SEAL.]

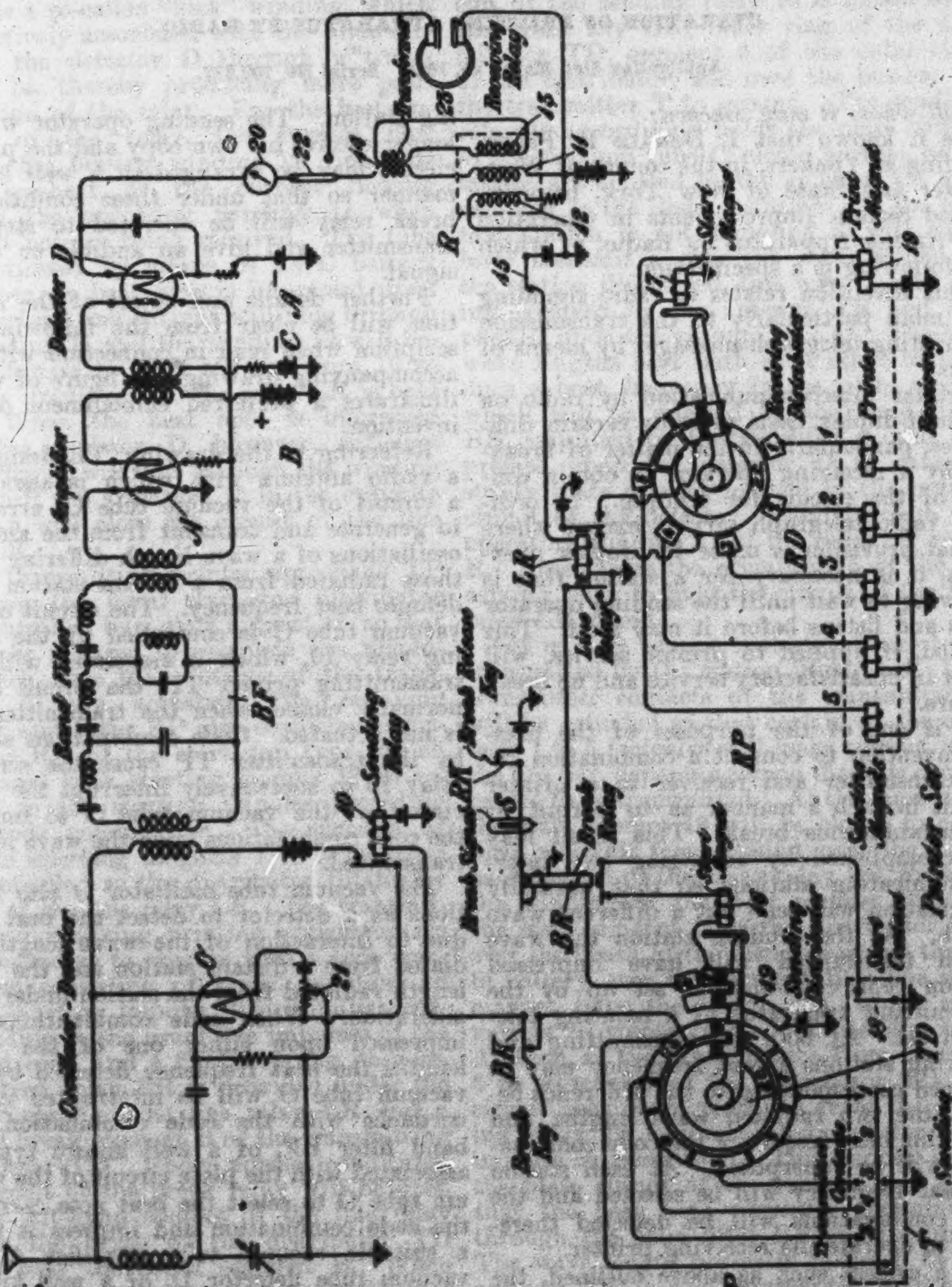
WM. A. KINNAN,
Acting Commissioner of Patents.

May 5, 1925. **1,536,130**

D. B. PERRY

OPERATION OF PRINTING APPARATUS BY RADIO

Filed March 29, 1924



INVENTOR

D.B. Perry

BY

ATTORNEY

Patented May 5, 1925. 1,536,130

UNITED STATES PATENT OFFICE.

DONALD B. PERRY, OF YONKERS, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

OPERATION OF PRINTING APPARATUS BY RADIO.

Applicatic filed March 29, 1924. Serial No. 702,877.

To all whom it may concern:

Be it known that I, DONALD B. PERRY, residing at Yonkers, in the county of Westchester and State of New York, have invented certain Improvements in Operation of Printing Apparatus by Radio, of which the following is a specification.

This invention relates to radio signaling and more particularly to the transmission of printing telegraph messages by means of radio.

Printer intercommunication by radio on the half-duplex basis presents certain difficulties, particularly in the matter of breaking by a receiving operator to obtain control of the circuit for sending. In ordinary radio telegraph service, except where special provision is made for duplex operation, it is necessary for a station that is receiving to wait until the sending operator stops and listens before it may send. This method, if applied to printer service, will result in unsatisfactory service and no break feature.

It is one of the purposes of the present invention to connect a combination radio transmitter and receiver to a printer circuit in such a manner as to permit of an instantaneous break. This result may be accomplished by arranging two intercommunicating stations so that normally each station will send out a different wave length. At the sending station the wave length transmitted will have impressed thereon code combinations set up by the transmitting apparatus of a printing telegraph set. At both the transmitting and receiving stations a beat frequency may be obtained corresponding to the difference between the two radiated wave lengths, and upon this beat frequency the code combinations will be superposed. At each station the beat frequency will be selected and the code combinations will be detected therefrom to operate the receiving printer.

In a system such as above outlined, the receiving station will be radiating a continuous wave. By merely interrupting the continuous wave emitted from the receiving station the receiving operator may break the circuit, for the beat frequency will no longer be present and consequently the code combination sent out from the transmitting station will not be impressed upon the final detector at either the transmitting or receiving station. The sending operator will no longer receive his own copy and the printer circuit may be arranged in a well known manner so that under these conditions a break relay will be operated to stop the transmitter and give an audible or visual signal.

Further details and object of the invention will be clear from the following description when read in connection with the accompanying drawing, the figure of which illustrates a preferred embodiment of the invention.

Referring to the drawing, TR designates a radio antenna with which is associated a circuit of the vacuum tube O, arranged to generate and transmit from the antenna oscillations of a wave length differing from those radiated from a distant station by a definite beat frequency. The circuit of the vacuum tube O is controlled by the sending relay 10, which is associated with the transmitting printer TP, the circuit being normally closed when the transmitter TP is not actuated. Code combinations set up by the transmitter TP cause the sending relay 10 to successively interrupt the plate circuit of the vacuum tube O to impress the code combinations upon the wave length transmitted.

The vacuum tube oscillator O also functions as a detector to detect the beat note due to interaction of the wave length radiated from a distant station and the wave length radiated from the station under consideration. When code combinations are impressed upon either one of the wave lengths the beat frequency detected by the vacuum tube O will be interrupted in accordance with the code combination. A band filter BF, of a well known type, is associated with the plate circuit of the vacuum tube O to select the beat note carrying the code combination and impress it upon a suitable vacuum tube amplifier A. A vacuum tube detector D, of a well known type, is associated with the output circuit of the amplifier and functions to detect from the beat note the code combination which is impressed upon one or the other of the radio frequencies, depending upon whether the station illustrated is transmitting or whether the distant station is transmitting.

A receiving relay R is provided, said receiving relay having three windings. One

of the windings 11 is included in the plate circuit of the detector D. The biasing winding 12 is connected in circuit with the source of plate current through a suitable resistance and is magnetically opposed to the operating winding 11. The third winding 13 is a so-called "kick" winding, which is inductively associated with the plate circuit of the detector D through a transformer 14, thereby producing more positive action of the relay. For the best operation of the relay, the current flow through the biasing winding 12 should be about one-half of the current flowing through the operating winding 11 when the beat note is being received. The tube is so adjusted by means of its C battery that when no beat note is impressed upon the detector D no current will flow through the winding 11 and the winding 12 will become effective to shift the armature 15 so that the circuit of the line relay LR is held open. When the beat note is impressed upon the detector D, however, sufficient plate current will flow through the winding 11 to shift the armature 15 in the opposite direction and close the circuit of the line relay LR.

The transmitting printer apparatus TP comprises the usual start-stop distributor TD, controlled by a start magnet 16, so that it will be released to complete one revolution each time the contacts of the transmitter T are actuated. The receiving printer apparatus RP also comprises a distributor RD of the start-stop type, which is released by a starting magnet 17 in response to the starting impulse preceding each code combination. The circuits of suitable selecting magnets 1 to 5 inclusive are controlled as the distributor rotates by means of the line relay LR. The transmitting and receiving printing apparatus are so arranged as to operate with a code combination consisting of seven impulses, an initial starting impulse, five impulses corresponding to the usual five impulses of the Baudot code, and a final stopping impulse.

A break relay BR is provided under the joint control of the line relay LR and a special break segment B of the transmitting distributor TD. Under normal conditions, the circuit of the break relay will be open at the left-hand contact of the line relay LR as the brush of the distributor TD passes over the break segment B. When the beat note is not present, as is the case when the break signal is transmitted by means of the break key BK of the other station, the circuit of the break relay BR will be closed by the line relay LR as the brush of the transmitting distributor TD passes over the break segment B. The break relay operates to light a lamp S and to hold open the circuit of the start magnet 16 to prevent further operation of the transmitting distributor.

Further details of the invention will now be clear from the description of the operation, which is as follows: When the transmitting printer TP is not actuated, the circuit of the sending relay 10 is closed over the break key BK, inner ring of the distributor TD, segment 6 of the outer ring of the distributor, and over the bus-bar of the transmitter T to ground. The sending relay 10 accordingly holds the plate circuit of the vacuum tube O closed so that oscillations are emitted by the antenna TR and radiated to the distant station. If the distant station is not signaling it will similarly transmit a different wave length to the station illustrated, this wave length being received by the antenna TR and impressed upon the vacuum tube O. The two wave lengths beat with each other to produce a beat frequency in the plate circuit which will be selected by the band filter BF, amplified by the amplifier A and impressed upon the detector D to cause a steady plate current to flow in the output circuit of the detector D and through the operating winding 11 of the receiving relay R. This causes the armature 15 of the receiving relay to hold the circuit of the line relay LR closed.

Let us now assume that signals are to be transmitted by the station illustrated. The transmitter contacts of the transmitter T will be actuated so that certain of the contacts 1 to 5 inclusive will make contact with the bus-bar, depending upon the code combination to be transmitted. At the same time, the start contact 18 will be closed to complete a circuit from ground, over the lower back contact of the break relay BR, through the winding of the start magnet 16, over the start segment S of the distributor TD, over the brush of the distributor and thence to battery over the segment 19. The start magnet trips the brush arm, which commences to rotate in a clockwise direction. As soon as the brush passes from segment 6 to segment 7 of the distributor TD, the circuit previously described from the sending relay 10 is interrupted and the start impulse is transmitted. This impulse opens the plate circuit of the vacuum tube O so that the beat note normally transmitted through the band filter BF is interrupted. The wave length normally radiated by the antenna TR is also interrupted so that at the distant station only the wave length normally radiated at the distant station will appear in the circuit of the oscillator at said distant station. Consequently, the beat note will not appear in the plate circuit of the oscillator at that station and will accordingly not be transmitted through the band filter corresponding to BF.

Returning to the station illustrated, the interruption of the beat note causes the plate current normally flowing in the output circuit of the detector D to be interrupted with the result that the biasing winding 12 shifts the armature 15 of the receiving relay R and opens the circuit of the line relay LR. A circuit is therefore completed from battery, over the back right-hand contact of relay LR, over a segment of the inner ring of the receiving distributor RD, over the brush arm of the distributor, and a segment of the outer ring of the distributor RD and through the winding of the start magnet 17 to ground. The start magnet accordingly trips the brush arm of the receiving distributor RD so that the brush arm begins to rotate in a clockwise direction. A similar action of the receiving apparatus takes place at the distant station.

As the brush arm of the transmitting distributor TD continues to rotate, it passes over the segments 1 to 5 inclusive of the outer ring of the distributor and thereby transmits either open or closed circuit impulses to the sending relay 10, depending upon the selective position of the contacts of the transmitter T. As the brush arm passes over a grounded transmitting segment the relay 10 will close the plate circuit of the oscillator O so that the normal wave length of the station will be radiated and a beat note will appear in the plate circuit due to the interaction of the radiated wave length and the received wave length. A similar beat frequency will, of course, be produced in the plate circuit of the oscillator tube at the distant receiving station. At both stations the beat frequency will be passed through the filter BF, amplified by the amplifier A and impressed upon the detector D to produce a direct current component through the operating winding 11 of the receiving relay R. This causes the contact 15 to close the circuit of the line relay LR.

As the brush arm of the transmitting distributor TD passes over an ungrounded transmitting segment, the circuit of the sending relay 10 will be open and the ensuing circuit operation will be the same as that described in connection with the transmission of the starting impulse. In short, each time the sending relay 10 transmits a closed circuit impulse the receiving relay LR at the local station and the corresponding relay at the distant station receive a closed circuit impulse. Likewise, each time the sending relay 10 transmits an open circuit impulse the circuit of the line relay LR at the local station and the circuit of the similar relay at the distant station will be open.

As the brush arm of the receiving distributor RD rotates it passes over the successive segments 1 to 5 inclusive of its outer ring coincident with the receiving of an open or closed circuit impulse through the line relay LR. If a closed circuit impulse is received a circuit will be completed over the left-hand front contact of the line relay and over the corresponding segment in the outer ring of the receiving distributor RD to one of the selecting magnets 1 to 5 inclusive. If an open circuit impulse is received by the line relay the circuit of the corresponding selecting magnet will not be completed. A similar operation takes place at the receiving printer of the distant station.

As the brush arm of the transmitting distributor TD passes onto the sixth segment of the outer ring a closed circuit condition is established for the sending relay 10 and the final step impulse is transmitted. The line relay LR accordingly receives a closed circuit impulse, as does the similar line relay at the distant station. Consequently, as the brush arm of the receiving distributor RD returns to its initial position the circuit of the start magnet 17 will be held open at the right-hand contact of the line relay LR until the start impulse of the succeeding code combination is transmitted. The brush arm accordingly is brought to rest by coaction with the latch of the start magnet. Just before the brush arm passes to its initial position it closes a circuit from the grounded segment of the inner ring of the receiving distributor and over the corresponding segment in the outer ring, through the print magnet 19, which causes a character to be printed, determined by the combination of selecting magnets actuated during the selecting operation, as is well understood in the art. The operation of the receiving printer at the distant receiving station will be similar to that just described.

Let us now assume that the operator at the distant receiving station desires to break in. The distant operator will then open the key corresponding to BK at that station, thereby holding open the circuit of the sending relay corresponding to 10 at that station. This will continuously interrupt the plate circuit of the oscillator corresponding to O at the distant receiving station, with the result that the wave length normally radiated from the distant station will no longer be received in the circuit of the oscillator O at the station illustrated. The beat note will therefore no longer be transmitted through the band filter BF and no closed circuit impulses will pass through the operating winding 11 of the receiving relay R. Consequently, the armature 15 of the receiving relay R will hold open the circuit of the line relay LR as long as the break key BK is held open at the distant receiving station. As the brush arm of the transmitting distributor TD passes over the sixth segment

of the outer ring of the distributor and returns to its normal position the closed circuit impulse transmitted to the sending relay 10 will be ineffective to transmit a closed circuit impulse to the line relay LR by reason of the absence of the beat note. As a consequence, a circuit will be completed from ground, over the left-hand back contact of the line relay LR, through the lower winding of the break relay BR, over the break segment B, brush and segment 19 of the distributor TD to battery. A momentary circuit is thus closed through the lower winding of the break relay as the brush arm passes over the break segment B so that the break relay BR is energized. A circuit is completed by the break relay through its locking winding over its upper front contact in series with the break signal S. At its lower armature the break relay BR holds open the circuit of the start magnet 16 and when the brush arm 19 comes to rest the brush arm can no longer be released in response to the closing of the start contact 18 as the sender T is further operated.

Upon observing the signal lamp S the operator at the station illustrated (which, as described, was sending) will open the release key RK, thereby unlocking the break relay BR. The operator also ceases to transmit by means of the transmitter T as soon as the break signal is observed, and as the circuit is now in its normal position the operator at the distant station may begin to transmit signals in the opposite direction. The transmission of signals from the distant station after the breaking operation will be obvious without further description as the circuit at the distant station is identical in all respects with that illustrated.

To aid in properly tuning the variable condenser in the circuit of the antenna TR, an ammeter 20 is shown connected in circuit with the operating winding of the receiving relay R. A change in the adjustment of the tuning condenser will vary the frequency of the beat note, assuming that the distant station is emitting a constant frequency. The maximum ammeter reading will indicate the beat note best transmitted through the band filter and the optimum setting of the variable condenser.

The system may be expanded to give intercommunication between more than two stations. In this case, each station will normally have assigned to it a "stand-by" wave length which it emits when not signaling. The stand-by wave length for each station will, of course, be different. When any particular station desires to signal another station the operator will adjust the antenna capacity to tune the output of the oscillator O to a frequency near that emitted by the desired station, thereby producing a beat note, which will be passed through the filter BF. The amplitude of the wave radiated should be reduced while tuning in in order to prevent interference in case the desired station is in communication with some other station. For this purpose, the grid connection of the oscillator may be varied, by means of the adjustable resistance 21, to increase the negative potential in the grid until the amplitude of the oscillations radiated is so small as not to cause interference with the distant station. The operator, while tuning, will throw the switch 22 to substitute a telephone receiver 23 for the receiving relay R. This is done for the reason that the operator will determine whether or not the desired station is signaling by receiving the signals transmitted from the distant intercommunicating stations and these signals will be so weak, because of the reduced amplitude of the frequency emitted by the station which is tuning in, that they will not operate the receiving relay. They may be readily heard in the receiver 23, however, so that the operator will know that the desired station is busy.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. In a radio signaling system, a plurality of intercommunicating stations, each station emitting waves of a different frequency, means at each station for producing a beat frequency from the two waves, means at each station for superposing telegraph signals on the wave emitted by that station whereby similar signals are superposed upon the beat frequency produced at each station, means whereby the wave which is emitted from the station which is receiving may be interrupted when the receiving operator desires to break in, thereby causing the beat frequency to cease, and means at the station which is sending responsive to the interruption of the beat frequency to operate a break signal at said station.

2. In a radio signaling system, a plurality of intercommunicating stations, each emitting a wave having a different frequency, means at each station to produce a beat frequency between the wave emitted and the wave received, means at each station to vary the wave emitted from that station in accordance with signal impulses, thereby producing a corresponding variation in the beat frequency produced at each station, means to detect signals from the beat frequency at each station, and means at the station which is receiving signals for interrupting the wave emitted from that station when it is desired to break in, thereby interrupting the beat frequency at each sta-

tion, and means at the station which is sending responsive to the interruption of the beat frequency to actuate a signal to indicate the break.

3. In a radio signaling system, a plurality of intercommunicating stations, each emitting a wave having a different frequency, means at each station to produce a beat frequency by the interaction of the wave emitted with the wave received, an automatic signal transmitter at each station, means controlled by said automatic signal transmitter to impress corresponding signal variations upon the wave emitted from that station, thereby producing similar signal variations upon the beat frequency at each station, means to detect the transmitted signals produced by the automatic signal transmitter from the beat frequency at each station, means at the station which is receiving for interrupting the wave emitted therefrom when it is desired to break, thereby interrupting the beat frequency at both stations, and means responsive to the interruption of the beat frequency at the sending station to stop said automatic signal transmitter.

4. In a radio signaling system, a plurality of intercommunicating stations, each emitting a wave having a different frequency, means at each station to produce a beat frequency by the interaction of the wave emitted with the wave received, an automatic signal transmitter at each station, means controlled by said automatic signal transmitter to impress corresponding signal variations upon the wave emitted from that station, thereby producing similar signal variations upon the beat frequency at each station, means to detect the transmitted signals produced by the automatic signal transmitter from the beat frequency at each station, means at the station which is receiving for interrupting the wave emitted therefrom when it is desired to break, thereby interrupting the beat frequency at both stations, and means responsive to the interruption of the beat frequency at the sending station to stop said automatic signal transmitter and actuate a signal to indicate the break.

5. In a radio signaling system, a plurality of intercommunicating stations, each emitting a wave having a different frequency, means to produce a beat frequency at each station by the interaction of the wave emitted with the wave received thereat, a printing telegraph transmitter at each station, means controlled by said transmitter at a station which is signaling for impressing code impulses upon the wave emitted from that station, thereby causing similar code impulses to be superposed upon the beat frequencies produced at both stations, means to detect said code impulses from the beat frequency at each station, a receiving printer at each station responsive to the detected code impulses to print a character corresponding to each code combination, means at the station which is receiving for interrupting the wave emitted from that station when it is desired to transmit a break signal, thereby interrupting the beat frequency at both stations, and means responsive to the interruption of the beat frequency at the station which is sending to stop said printing telegraph transmitter.

6. In a radio signaling system, a plurality of intercommunicating stations, each emitting a wave having a different frequency, means to produce a beat frequency at each station by the interaction of the wave emitted with the wave received thereat, a printing telegraph transmitter at each station, means controlled by said transmitter at a station which is signaling for impressing code impulses upon the wave emitted from that station, thereby causing similar code impulses to be superposed upon the beat frequency produced at each station, means to detect said code impulses from the beat frequency at each station, a receiving printer at each station responsive to the detected code impulses to print a character corresponding to each code combination, means at the station which is receiving for interrupting the wave emitted from that station when it is desired to transmit a break signal, thereby interrupting the beat frequency at both stations, and means responsive to the interruption of the beat frequency at the station which is sending to stop said printing telegraph transmitter and actuate a signal to indicate the break.

7. In a radio signaling system, a plurality of intercommunicating stations, each emitting a wave having a different frequency, means at each station to produce a beat frequency by the interaction of the wave emitted from that station with the wave being received thereat, a printing telegraph transmitter at each station for setting up code combinations, a distributor associated with each transmitter for successively impressing the impulses of the code combination upon the wave emitted from the corresponding station, thereby causing similar code combinations to be impressed upon the beat frequency produced at both stations, means at each station for detecting from the beat frequency the code combinations impressed thereon, a receiving printer at each station, a distributor associated with each receiving printer for impressing upon the elements of the printer the impulses of the detected code combination, means at the station which is receiving signals for interrupting the wave emitted therefrom when it is desired to transmit a break signal, thereby interrupting the beat frequency at both stations, and means responsive to the interrup-

tion of the beat frequency at the station which is sending to stop the distributor associated with the transmitter thereat.

8. In a radio signaling system, a plurality of intercommunicating stations, each emitting a wave having a different frequency, means at each station to produce a beat frequency by the interaction of the wave emitted from that station with the wave being received thereat, a printing telegraph transmitter at each station for setting up code combinations, a distributor associated with each transmitter for successively impressing the impulses of the code combination upon the wave emitted from the corresponding station, thereby causing similar code combinations to be impressed upon the beat frequency produced at each station, means at each station for detecting from the beat frequency the code combination upon the wave emitted from the corresponding station, thereby causing similar code combinations to be impressed upon the beat frequency produced at both stations, means at each station for detecting from the beat frequency the code combinations impressed thereon, a receiving printer at each station, a distributor associated with each receiving printer for impressing upon the elements of the printer the impulses of the detected code combination, means at the station which is receiving signals for interrupting the wave emitted therefrom when it is desired to transmit a break signal, thereby interrupting the beat frequency at each station, and means responsive to the interruption of the beat frequency at the station which is sending to stop the distributor associated with the transmitter thereat and to actuate a special signal to indicate the break.

9. In a radio signaling system, a plurality of intercommunicating stations, each station emitting a wave having a different frequency, means to produce a beat frequency at each station by the interaction of the wave emitted with the wave received thereat, a printing telegraph transmitter at each station, means controlled at said transmitter at the station which is signaling for impressing code impulses upon the wave emitted from that station, thereby causing similar code impulses to be superposed on the beat frequencies produced at both stations, means to detect said code impulses from the beat frequency at each station, a receiving printer at each station responsive to the detected code impulses to print a character corresponding to each code combination, means at the station which is receiving for interrupting the wave emitted from that station when it is desired to transmit a break signal, thereby interrupting the beat frequency at both stations so that the receiving printer at the transmitting station will not record the signals transmitted.

10. In a radio signaling system, a plurality of intercommunicating stations, each emitting a wave of a different frequency, means at each station to produce a beat frequency between the wave emitted and the wave received, means at each station to vary the wave emitted from that station in accordance with said signaling impulses, thereby producing a corresponding variation in the beat frequency produced at each station, means to select the beat frequency at each station, means to detect signals from the beat frequency at each station, and means at the station which is receiving signals for interrupting the wave emitted from that station when it is desired to break in, thereby interrupting the beat frequency at each station and preventing further operation of the detecting means.

In testimony whereof, I have signed my name to this specification this 26th day of March, 1924.

DONALD B. PERRY.

March 2, 1926. 1,574,780

H. A. AFFEL

MEANS FOR AND METHOD OF MODULATION

Filed Oct. 5, 1921 3 Sheets-Sheet 1

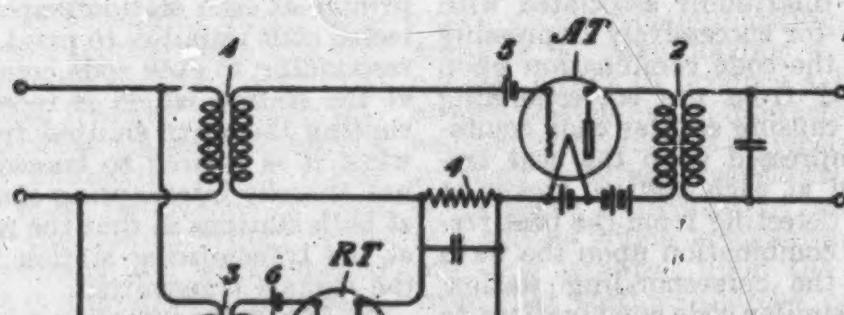


Fig. 1

Fig. 2

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MEANS FOR AND METHOD OF MODULATION

Filed Oct. 5, 1921 3 Sheets-Sheet 2

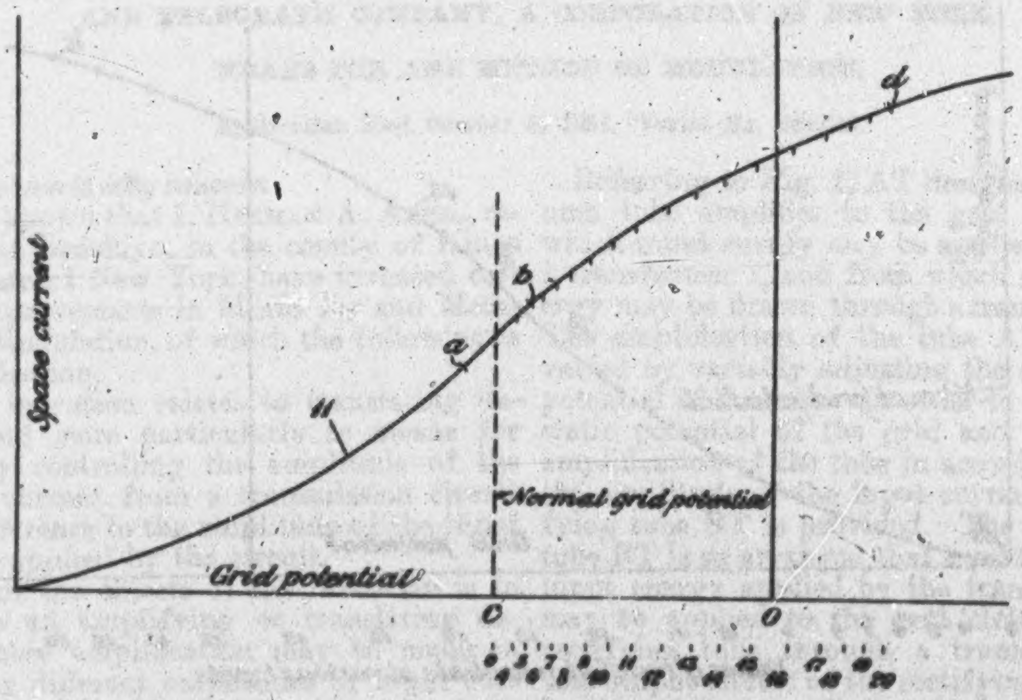

Fig. 3

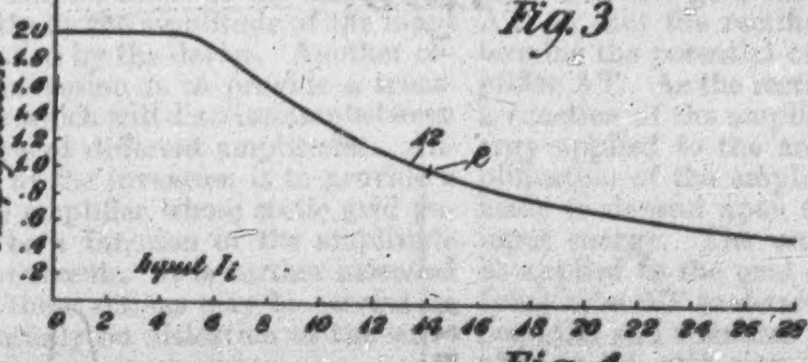

Fig. 4

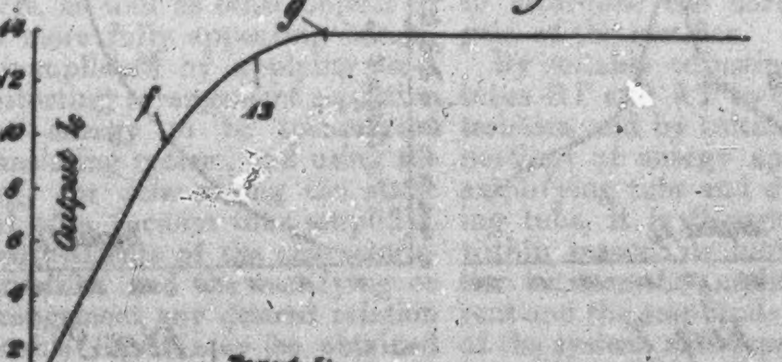

Fig. 5

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March 2 , 1926. H. A. AFFEL 1,574,780

MEANS FOR AND METHOD OF MODULATION

Filed Oct. 5, 1921 3 Sheets-Sheet 3

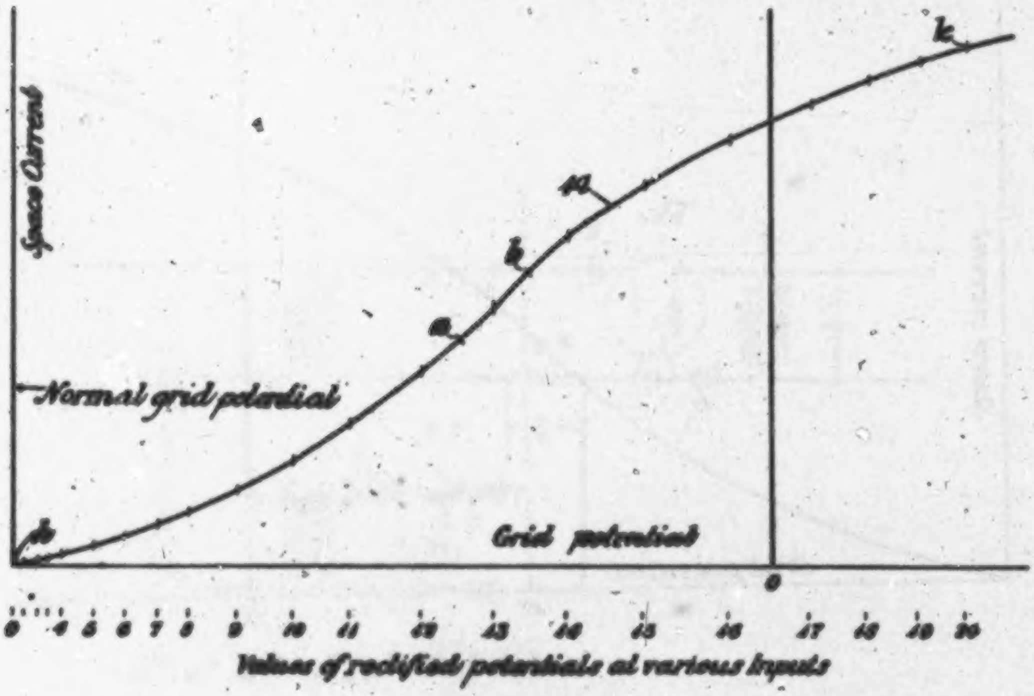

Fig 6

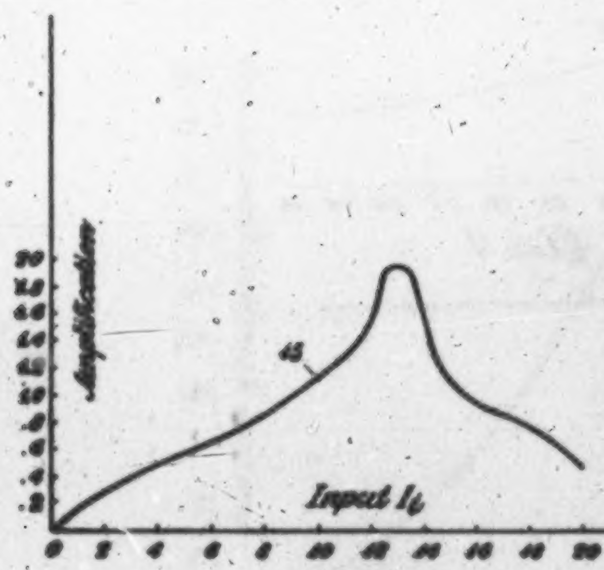

Fig. 7

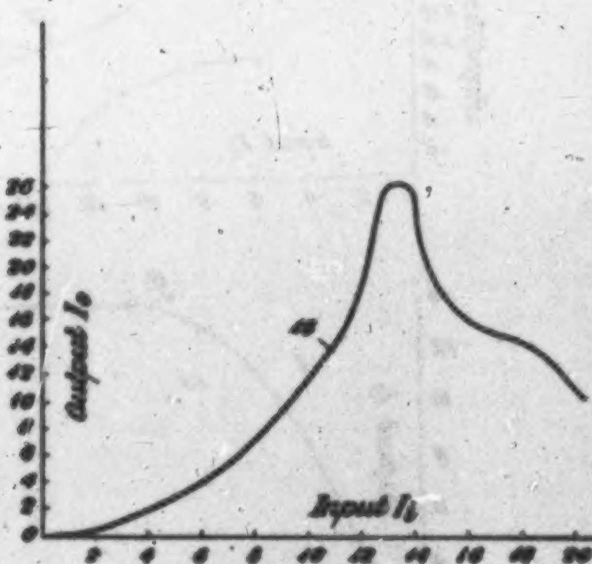

Fig. 8

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Patented Mar. 2, 1926. **1,574,780**

UNITED STATES PATENT OFFICE.

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MEANS FOR AND METHOD OF MODULATION.

Application filed October 5, 1921. Serial No. [illegible].

To all whom it may concern:

Be it known that I, HERMAN A. AFFEL, residing at Brooklyn, in the county of Kings and State of New York, have invented certain Improvements in Means for and Methods of Modulation, of which the following is a specification.

This invention relates to translating devices and more particularly to means for variably controlling the amplitude of the output current from a transmission circuit with reference to the amplitude of the input current applied by the circuit.

One of the objects of the invention is to produce an amplifying or translating device whose amplification may be made to vary for different amplitudes of input current. Another object of the invention is to control the amplification of an amplifying device directly by the amplitude of the input current supplied by the device. Another object of the invention is to provide a translating device which will discriminate between input currents of different amplitudes. Another object of the invention is to provide a vacuum tube amplifier whose static grid potential will be a function of the amplitude of the input currents. It is further intended that any of these actions may be carried on with substantially no distortion of the wave form of the incoming current.

These objects, as well as other objects of the invention more fully appearing hereinafter, are accomplished by applying to a rectifier or distorting arrangement a portion of the input energy to be transmitted through a translating system, and using the rectified energy for determining the static grid potential of a vacuum tube amplifier. By suitable adjustments of the characteristics of the amplifier and the rectifying or distorting arrangement any desired relation within reasonable limits may be obtained between the amplitudes of the input and output currents of the system.

The invention may now be more fully understood from the following description when read in connection with the accompanying drawing, Figure 1 of which is a circuit diagram of an arrangement embodying the principles of the invention, and Figs. 2 to 8 inclusive of which are curves illustrating the operation of the arrangement disclosed in Fig. 1.

Referring to Fig. 1, AT designates a vacuum tube amplifier to the grid circuit of which input energy may be applied through a transformer 1, and from which output energy may be drawn through a transformer 2. The amplification of the tube AT may be varied by variably adjusting the static grid potential of the tube. In order to adjust the static potential of the grid and hence the amplification of the tube in accordance with the amplitude of the input current, a rectifying tube RT is provided. The rectifying tube RT is so arranged that a portion of the input energy applied by the transformer 1 may be applied to the grid circuit of the rectifying tube through a transformer 3. The output circuit of the rectifying tube RT is connected across the terminals of a resistance 4 in the grid circuit of the amplifier AT, so that the rectified potential will determine the potential of the grid of the amplifier AT. As the rectified potential will be a function of the amplitude of the input energy applied to the amplifier AT, the amplification of the amplifier AT may thus be made to depend upon the amplitude of the input energy. The usual C battery 5 may be applied to the grid circuit of the amplifying tube AT to determine its normal grid potential and a similar battery 6 may be applied to the grid circuit of the rectifier RT to determine the normal potential of the grid of the rectifier.

By suitably adjusting the elements of the tubes RT and AT to obtain desired characteristics, and by suitably adjusting the proportions of energy applied directly to the amplifying tube and directly to the rectifying tube, it is thought possible to obtain, within reasonable limits, any desired relation between the amplitude of the input current and the amplitude of the output current of the system, and depending upon these adjustments, different operating requirements may be met.

For example, the translating arrangement above described may be used to equalize the current output of the system for input amplitudes above some critical value. This would permit of stabilizing the operation of some relay or other translating device independent of substantial input current variations.

In order to understand quantitatively how

such a result may be obtained, attention is called to the curves of Figs. 2 to 5 inclusive. In Fig. 2 the curve 10 shows the variation of the potential of the rectified space current of the tube RT for different amplitudes of input current. This curve, it will be noted, is similar in form to the usual characteristic curve of a three-element vacuum tube as plotted between grid potential and space current; in fact, the curve 10 may be considered as a reproducton of the characteristic curve of the tube since the input energy is a direct function of the grid potential, and the potential of the rectified space current is directly proportional to the plate current of the tube.

In Fig. 3, 11 may be taken as the characteristic curve of the amplifying tube AT, the curve being plotted between grid potential and space or plate current, as is the common practice. This curve may be given various forms by suitable adjustments of the constants of the tube as is well known, and in the instance given, the characteristic curve 11 is substantially a straight line between the points *a* and *b*. Over this portion of the curve the amplification will be constant. Above the point *b* the curve gradually flattens out so that the slope of the curve is decreased. The same is true of the portion of the curve below the point *a*. As the amplification of the tube depends upon the slope of the characteristic curve over the range in which the tube is operating, it will be apparent that the amplification gradually decreases above the point *b* until the slope is decreased to such a point that, depending of course on the absolute values of the constants involved, an actual loss in transmission may possibly occur, instead of a gain. The same thing may hold true for the portion of the curve below the point *a*.

Let us assume that with the grid of the amplifying tube AT at neutral or zero potential a space current would flow as indicated at *o*. The potential of the grid battery 5 may be then so fixed that the tube will normally operate at the point *c*, which is here taken as the midpoint of the straight line portion of the characteristic. Let us further assume that the amplitude of the input energy, as applied to the grid of the amplifying tube AT, is sufficiently small so that at any given instant the variation in amplitude will be within a relatively narrow portion of the characteristic. This will insure a minimum distortion of the input wave form. Let us assume that the rectified output potential of the rectifying tube RT will be of sufficient amplitude in the case of the greatest amount of input energy to be considered so that when said rectified potential is applied to the grid circuit of the amplifier, it will shift the operating point of the curve from the point *c* to a point well along the upper portion of the curve, as for example, the point *d*. In general these assumptions would probably mean that tube AT would be of larger physical dimensions that tube RT.

In the case assumed, the rectified potential will be applied in such a direction as to oppose the potential of the grid battery 5, so that as the amplitude of the input energy is increased the normal grid potential will become less and less negative, thus shifting the operating point further upward over the curve. The values of the controlling potentials for the amplifying tube for different values of input current may be obtained from the curve 10 of Fig. 2. These values are indicated by the points laid out immediately below the horizontal axis of the curve, the points being designated by the numbers indicating the corresponding input amplitudes. In other words, the points indicate values of rectified potential but the numbers applied to the points refer to corresponding input amplitudes.

The amplification of the tube at any given input amplitude may be obtained by determining the slope of the curve 11 at a point immediately above the number designating a given input potential in Fig. 3. Curve 12 of Fig. 4 is a plot of the amplification of the tube for different amplitudes of input current, as determined from the curve 11 of Fig. 3. For example, if the input current applied to the amplifier is zero, the static grid potential of the amplifying tube will be the normal grid potential indicated at *c* in Fig. 3. At this point the slope of the curve is forty-five degrees, which is arbitrarily assumed, for purposes of illustration, to correspond to an amplification of two times. As the amplitude of the input current is increased up to five units, the slope remains the same and hence the amplification as plotted in Fig. 4 is the same, consequently the curve 12 is horizontal out to this point. As the amplitude is increased the slope of the curve decreases for amplitude beyond five units, so that the amplification correspondingly decreases. For example, for an input current of 14 units, in Fig. 2, the slope of the curve is such that the amplification is unity. As the slope decreases beyond this point with corresponding decrease in amplification, the functioning of the tube represents an actual loss in transmission. Thus, in the curve 12 of Fig. 4, the portion of the curve to the right of the point *e* represents a loss in transmission, and that portion of the curve to the left of the point *e* represents a gain.

In order to obtain a clear picture of the relation between the input amplitude and the output amplitude for the system, it is necessary to translate the values of amplification in Fig. 4 into values of output cur-

rent. Since the amplification is merely the ratio of the output current I_o to the input current I_i the value of the output current may be obtained for each value of input current by multiplying the input current by the amplification as obtained from the curve 12. The curve 13 of Fig. 5 is obtained by plotting input currents against the output currents thus obtained. An inspection of the curve 13 shows that up to the point *f*, corresponding to an input current of five units, the output current increases by a constant ratio so that the curve is a straight line to this point. As the amplification falls off beyond this point the slope of the curve changes and beyond the point *g*, corresponding to about eleven units of input current, the curve remains horizontal, in other words, for input currents greater than eleven units, the output current of the system will be constant.

This equalization of the amplitude of the output current for any input amplitude above a given limiting value may be obtained by suitable adjustment of the constants of the two tubes involved, and is not dependent upon the particular values above described, these values merely being assigned arbitrarily in order to obtain a quantitative understanding of the principles underlying this aspect of the invention. Other adjustments may be used to give different results, for example, by suitable adjustments, the apparatus may be made to function as a marginal discriminating device in which the greatest action of a relay or other piece of detecting apparatus in the output circuit obtains when the input current is of a particular value and values of input current greater or less than this particular value will be discriminated against. Such a device might be used, for example, in the reduction of interference in carrier or radio transmission systems. In such a case the normal signal would be received at the amplitude for which a maximum output current will obtain. If an interfering current of greater or less value than a signaling current is impressed upon the system, the output current will be considerably decreased, so that the marginal responsive device will be unaffected.

In order to obtain a quantitative idea of how the tube should be adjusted in order to secure this result, attention is called to the curves of Figs. 6, 7 and 8. In Fig. 6 the curve 14 is the characteristic curve of the amplifier AT plotted in the usual manner between grid potential and plate current. For purposes of illustration this curve is made identical with the curve 11 of Fig. 3, the amplification being uniform between points *a* and *b* and decreasing when the operation of the tube is at points beyond *a* and *b*.

It will be remembered that in order to obtain the equalization of the output current as above described, the apparatus of Fig. 1 was adjusted so that the amplifying tube operated from a point *c* intermediate between the points *a* and *b* to a point on the curve, as indicated at in Fig. 3. In the present instance it is proposed to operate along the curve from the point *h* to the point *k*. The grid battery 5 is therefore adjusted so that the normal grid potential will be negative, a sufficient number of volts to prevent any space current from flowing. While it is not necessary that the normal grid potential should be such as to prevent any space current from flowing, the grid should be normally sufficiently negative so that the tube would be operating on the lower part of its characteristic where the amplification is low.

The rectified controlling potential applied to the grid circuit from the tube RT must, in the case of the maximum input energy to be considered, be sufficient to shift the operating point of the curve to a point of low amplification on the upper part of the curve beyond the point *b*. Accordingly the constants of the tube RT ~~will be adjusted to increase its amplification of the component of the output potential to be applied to the amplifying tube will be increased so that the range of rectified potentials corresponding to various inputs will extend~~ from, say, the point *h* to the point *k* in Fig. 6. The various rectified potentials corresponding to the current input values will be obtained as before from the curve 10 of Fig. 2, and the points below the horizontal axis in Fig. 6 represent potentials corresponding to different input amplitudes.

As in the case of Fig. 3, the amplification for any given grid potential will depend upon the slope of the curve at that point. The rectified potentials applied to the grid circuit of the amplifying tube AT tend to neutralize the normally negative potential of the grid more and more as the amplitude of the input current increases. The amplification of the tube for a given input current may be obtained by determining the slope of the curve 14 at a point immediately above the number representing the desired input in the row of numbers below the horizontal axis of Fig. 6. By plotting the values of the amplification for different values of the input current in a manner similar to that described in connection with Fig. 4, the curve 15 of Fig. 7 will be obtained. From this curve it will be seen that the amplification for an input current of zero value will be zero and the amplification gradually increases to a maximum for an input current of 13 units, this input current corresponding to the intermediate point of the straight portion of the characteristic curve lying be-

tween *a* and *b* in Fig. 6. The amplification then decreases for further increase in the input current, this being due to the falling off of the slope of the curve 14 in Fig. 6.

The output current values may be obtained by multiplying the input current by the amplification, as described in connection with Fig. 5. By plotting input currents along the horizontal axis and output currents along the vertical axis, the curve 16 of Fig. 8 is obtained. An inspection of this curve shows that as the input current is increased up to a value in the neighborhood of 13 units, the output current increases, the increase being very rapid in the neighborhood of 13 units, which point corresponds to the maximum output current. For further increase in the amplitude of the input current, the output current falls off very rapidly. It follows at once from an inspection of the curve in Fig. 8, a system such as that described may be made highly discriminatory with regard to the amplitude of the input current.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. The method of varying the amplification of a vacuum tube amplifier which consists in producing a current whose amplitude is proportional to the envelope of the alternating input energy applied to the tube and in adjusting the static grid potential in accordance with the amplitude of the current so produced.

2. The method of controlling the amplification of a vacuum tube amplifier which consists in rectifying a portion of the input energy and applying the direct current component of the rectified energy to the grid circuit of the tube to determine the static potential thereof.

3. The method of controlling the amplification of a vacuum tube amplifier which consists in rectifying a portion of the input energy and applying the direct current component of the rectified energy to the grid circuit of said amplifier to adjust the amplification in accordance with the static potential applied by the grid.

4. The method of operating a translating circuit, including a three-element vacuum tube, which consists in producing a current whose amplitude is proportional to the envelope of the alternating input energy applied to the tube and in so controlling the static grid potential of the vacuum tube in accordance with the amplitude of the current so produced that a predetermined relation between the input energy applied to the system and the ouput energy from the system will be obtained.

5. The method of operating a translating circuit, including a three-element vacuum tube, which consists in producing a current whose amplitude is proportional to the envelope of the alternating input energy applied to the tube and in so controlling the static potential of the grid of the tube in accordance with the amplitude of the current so produced that the output energy will be a maximum for a predetermined amplitude of the input energy.

6. The method of operating a translating circuit, including a three-element vacuum tube, which consists in producing a current whose amplitude is proportional to the envelope of the alternating input energy applied to the tube and in so controlling the static potential of the grid of the tube in accordance with the amplitude of the current so produced that the system will discriminate against input energies having amplitudes less than a predetermined maximum.

7. The method of operating a translating circuit, including a three-element vacuum tube, which consists in producing a current whose amplitude is proportional to the envelope of the alternating input energy applied to the tube and in so controlling the static potential of the grid of the tube in accordance with the amplitude of the current so produced that the system will discriminate against input energies having amplitudes greater than a predetermined amplitude.

8. The method of operating a translating circuit, including a three-element vacuum tube, which consists in so controlling the static potential of the grid of the tube in accordance with the amplitude of the input energy that the system will transmit the greatest output energy for a predetermined input energy and the output energy will be less for input amplitudes either greater or less than the predetermined amplitude.

9. The method of operating a translating circuit, including a three-element vacuum tube, which consists in applying input energy to the tube, rectifying a portion of the input energy before it is applied to the tube, and so controlling the static potential of the tube by means of the direct current component of the rectified energy that a predetermined ratio between the input energy applied to the system and the output energy transmitted from the system will be obtained.

10. The method of operating a translating circuit, including a three-element vacuum tube, which consists in applying input energy to the tube, rectifying a portion of the input energy before it is applied to the

tube, and so controlling the static potential of the tube by means of the rectified energy that the system will discriminate against input energies having amplitudes less than a predetermined maximum.

11. The method of operating a translating circuit, including a three-element vacuum tube, which consists in applying input energy to the tube, rectifying a portion of the input energy before it is applied to the tube, and so controlling the static potential of the tube by means of the direct current component of the rectified energy that the system will discriminate against input energies having amplitudes greater than a predetermined amplitude.

12. The method of operating a translating circuit, including a three-element vacuum tube, which consists in applying input energy to the tube, rectifying a portion of the input energy before it is applied to the tube, and so controlling the static potential of the tube by means of the rectified energy that the system will transmit the greatest output energy for a predetermined input energy and the output energy will be less for input amplitudes either greater or less than the predetermined amplitude.

13. The method of operating a vacuum tube amplifier which consists in producing a current whose amplitude is proportional to the envelope of the alternating input energy applied to the tube and in shifting the operating point of the tube along its characteristic axis in accordance with the amplitude of the current so produced.

14. The method of operating a vacuum tube amplifier which consists in applying thereto energy variations whose maximum amplitude will be relatively small as compared with the total range of the tube, and shifting the operating point of the tube along its characteristic curve to a point determined by the amplitude of the envelope of the alternating energy variations applied thereto.

15. The method of operating a vacuum tube amplifier which consists in applying energy variations to said amplifier having an amplitude relatively small as compared with the range of the tube, rectifying a portion of the energy and applying the direct current component of the rectified potential to the grid circuit of the tube to shift the working point of the tube along its characteristic curve in accordance with the amplitude of the energy variations.

16. In a translating system, a three-element vacuum tube, means to apply energy variations to said tube, means to produce a current whose amplitude is proportional to the envelope of the alternating energy so applied, and means to adjust the working point of said tube along its characteristic axis in accordance with the amplitude of the current so produced.

17. In a translating system, a three-element vacuum tube, means to apply energy variations to said tube, means to rectify a portion of the energy of said variations, means to apply the direct current component of the rectified potential to said vacuum tube to shift its working point along its characteristic curve in accordance with the amplitude of the energy applied by the tube.

18. In a translating system, a three-element vacuum tube, means to apply alternating currents to the grid circuit of said tube, means controlled by said alternating current for producing a direct current potential whose value is determined by the amplitude of said alternating current, and means to apply said direct current potential to said vacuum tube to control its operating point.

19. In a translating system, a vacuum tube amplifier, means to apply alternating current to the input circuit of said amplifier, a vacuum tube rectifier, means to apply said alternating current to said vacuum tube rectifier, thereby producing rectified direct current, and means to control the static potential of the grid of said vacuum tube amplifier in accordance with the amplitude of said rectified direct current.

In testimony whereof, I have signed my name to this specification this 21st day of September 1921.

HERMAN A. AFFEL.

July 13, 1926. 1,592,710

J. SCOTT-TAGGART

MODULATION SYSTEM

Filed July 5, 1921 2 Sheets-Sheet 1

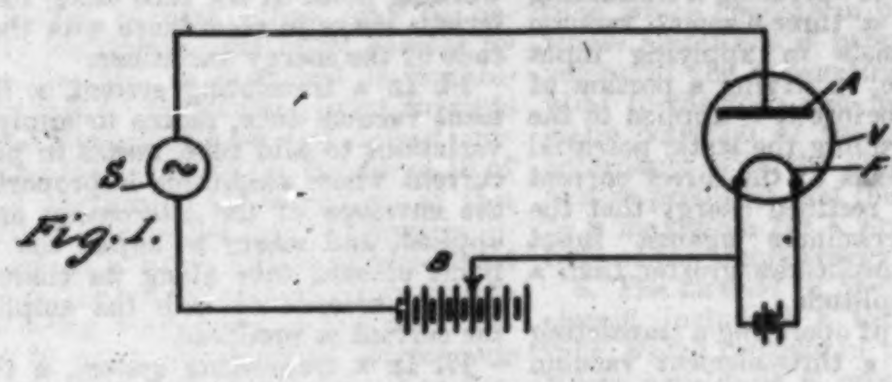


Fig. 1.

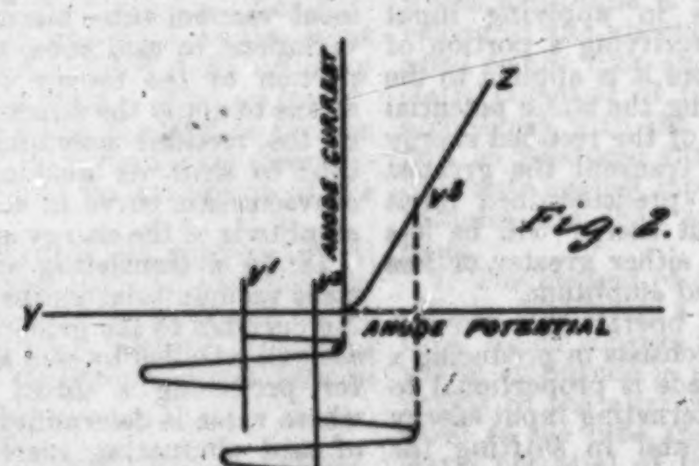


Fig. 2.

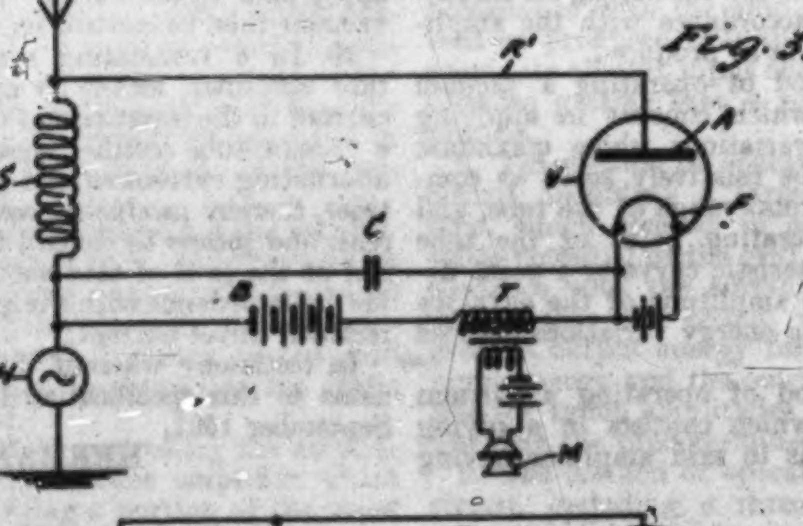


Fig. 3.

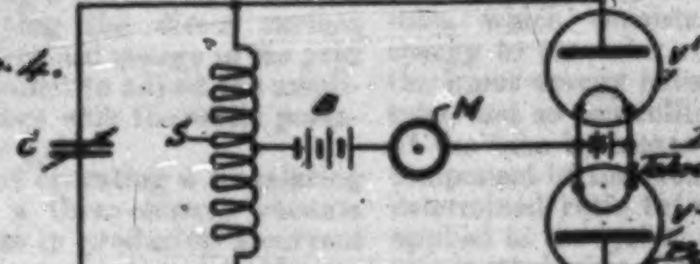


Fig. 4.

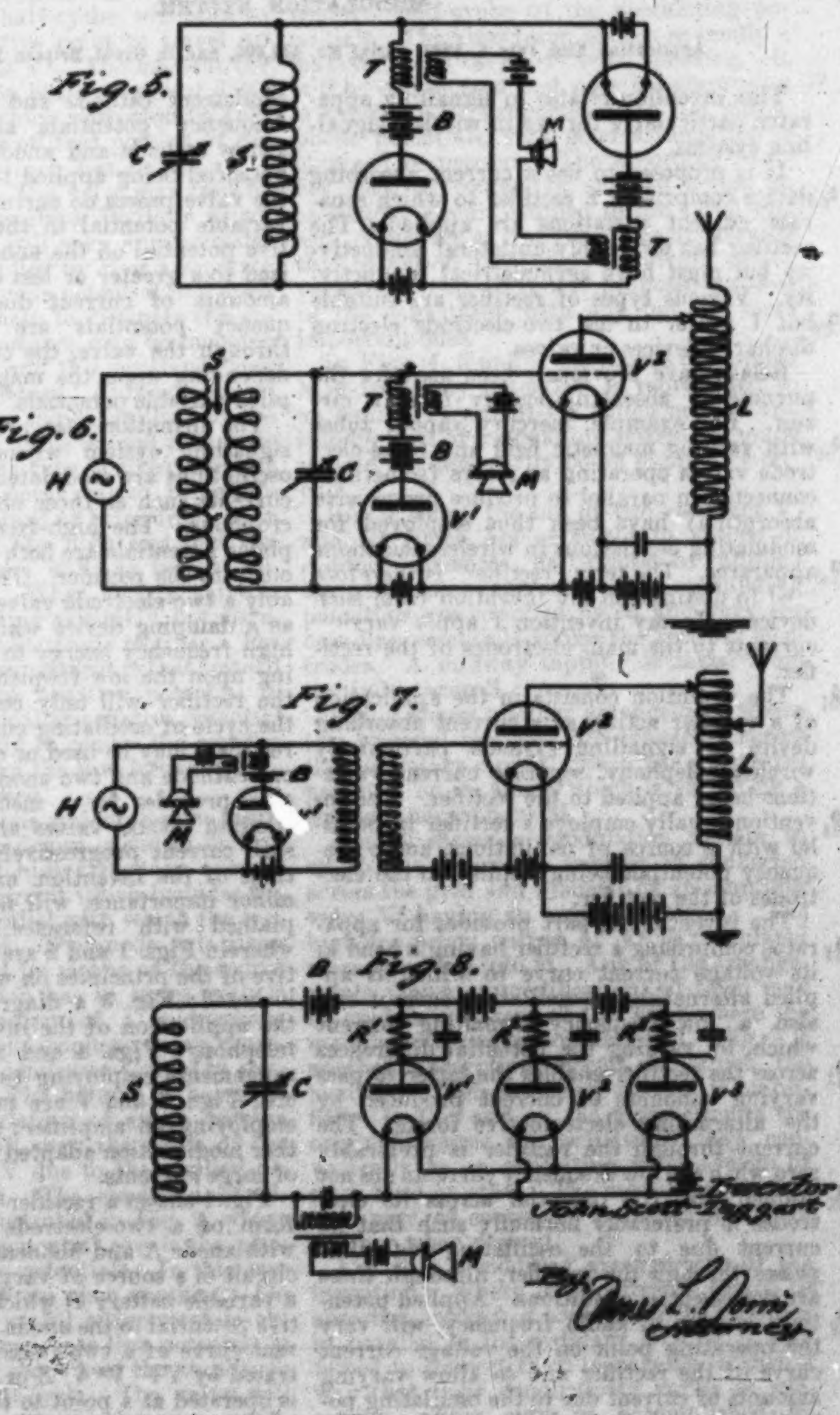
Inventor
John Scott-Taggart
By
Attorney

July 13, 1926. 1,592,710

J. SCOTT-TAGGART

MODULATION SYSTEM

Filed July 5. 1921 2 Sheets-Sheet 2



Patented July 13, 1926. 1,592,710

UNITED STATES PATENT OFFICE.

JOHN SCOTT-TAGGART, OF LONDON, ENGLAND.

MODULATION SYSTEM.

Application filed July 5, 1921, Serial No. 482,823, and in Great Britain July 17, 1920.

This invention relates to signalling apparatus particularly for use in wireless signalling systems.

It is proposed to use a current absorbing device comprising a rectifier to which separate current variations are applied. The rectifier has preferably unilateral conductivity but must have asymmetrical conductivity. Various types of rectifier are suitable but I prefer to use two-electrode electron discharge devices or valves.

Relays have previously been used for the purpose of absorbing energy from a circuit. For example, mercury vapour tubes with varying magnetic field and three-electrode valves operating as relays (sometimes connected in parallel to produce progressive absorption) have been thus employed for modulating oscillations in wireless telephone apparatus. The term "rectifier" is therefore used to distinguish my invention from such devices. In my invention I apply varying currents to the main electrodes of the rectifier.

The invention consists in the application of a rectifier acting as a current absorbing device to signalling systems, particularly wireless telephony, separate current variations being applied to the rectifier. The invention usually employs a rectifier in parallel with a source of oscillations, audio frequency potentials being applied to the electrodes of the rectifier.

The invention in part provides for apparatus comprising a rectifier having a bend in its voltage current curve to which is applied alternating or oscillating current and also a low frequency signalling current which, by varying the potential differences across the rectifier enables the latter to pass varying amounts of current produced by the alternating electromotive forces. The current through the rectifier is preferably zero when the low frequency currents are not applied and the potential across its electrodes is preferably normally such that no current due to the oscillating potentials passes through the rectifier, although these are not essential conditions. Applied potentials, usually of audio frequency, will vary the operating point on the voltage current curve of the rectifier and so allow varying amounts of current due to the oscillating potentials to pass through the rectifier. The rectifier which has been found most suitable is a two-electrode valve comprising an incandescent cathode and an anode. High-frequency potentials are usually applied across cathode and anode, a fixed negative potential being applied to the anode so that the valve passes no current. By applying a variable potential to the anode, the negative potential on the anode may be neutralized to a greater or less extent and varying amounts of current due to the high-frequency potentials are allowed to pass through the valve, the current thus passed depending upon the magnitude of the applied variable potentials.

The invention also provides for a radio signalling system wherein high-frequency oscillations are modulated by low frequency currents such as those obtained from a microphone. The high-frequency and microphone potentials are both applied simultaneously to the rectifier. The rectifier, preferably a two-electrode valve, may be arranged as a damping device which will absorb the high-frequency energy to an extent depending upon the low-frequency potentials. As the rectifier will only conduct one half of the cycle of oscillating current, two opposed rectifiers may be used or else a rectifier with one cathode and two anodes. The invention also provides for a method of absorption wherein several valves are arranged to absorb current progressively. These applications of the invention, excluding others of minor importance, will now be further explained with reference to the drawings, wherein Figs. 1 and 2 are diagrams illustrative of the principles on which the invention is based; Fig. 3 a diagram illustrative of the application of the invention to wireless telephony; Figs. 4 and 5 are modified arrangements employing two opposed rectifiers; Figs. 6 and 7 are modulation systems employing an amplifier; and Fig. 8 a further modification adapted for the absorption of large currents.

Fig. 1 shows a rectifier V which takes the form of a two-electrode thermionic valve with anode A and filament F. In the anode circuit is a source of varying current S and a variable battery B which provides a negative potential to the anode. The voltage-current curve of a two-electrode valve is illustrated by YV′ V² V³ Z in Fig. 2. The valve is operated at a point to the left of zero potential, for example V′. If the currents from S are oscillatory, the potential of the anode, as shown, does not become positive

but may become zero. Under these conditions the valve does not conduct. If, however, we lessen the effect of the negative potential on A, by decreasing B or applying a positive potential in series, the normal or base-line anode potential will become, say, V^2 and the positive half-cycles will tend to cause the representative point to travel up the curve to the point V^3. The moment the potential of A becomes positive current flows through the valve which now absorbs current and tends to cut off that portion of the positive half-cycle which lies to the right of zero anode volts. The valve may thus be used as an energy-absorbing device in which the energy diverted will vary approximately as the voltage applied by B or a separate source varying the anode potential in a positive direction. To help to dissipate the absorbed energy, a resistance may be included in the anode circuit and this resistance may be shunted by a condenser. Although a fixed negative potential is shown applied to the rectifier, yet when a valve is used it may be of the three-electrode type, a fixed negative potential which is never varied being applied to the grid instead of being inserted in the anode circuit. The high and low frequency potentials are still, as before, applied to the anode. When such a valve is used, it is not operating as a relay, but merely as a modified two-electrode rectifier. The advantage of the arrangement is that instead of applying a large negative potential to the anode, a much smaller negative potential is applied to the grid to render the rectifier non-conducting when the low-frequency potentials are not applied.

A wireless telephone which uses the rectifier as an absorbing device is shown in Fig. 3. A source H of high-frequency current supplies the aerial circuit which includes the inductance S in parallel with which the rectifier V is connected. The anode A is given a negative potential by means of the source of potential B which has in series with it the secondary winding of a microphone transformer T, the microphone being represented by M. The condenser C may be connected as shown. The battery B has such a value that a variation of anode voltage produced by M will vary the value of the current passed by V due to the applied oscillating potentials. The condition of affairs may be as illustrated in Fig. 2, where the fixed negative potential equals the positive high-frequency potentials. In this case the valve only conducts when speaking. On the other hand, a useful adjustment is obtained when the fixed base-line potential is such that it equals about half the amplitude of the positive half-cycle. The valve will now be absorbing energy when not speaking. When speaking, the positive half-cycles of microphone potential will lessen the negative base-line potential and cause a greater absorption of energy. The negative half-cycles will decrease the absorption of energy. A special but not convenient adjustment is obtained by making the anode potential zero and preferably applying only negative half-cycles of the modulating potentials. The absorption is thus normally a maximum and decreases when speaking. It will be readily seen that since the absorption is substantially proportional to the microphone potentials, very good articulation is obtained in practice. The absorbing rectifier may, of course, be shunted across an oscillatory circuit coupled to the aerial system. There are so many methods of carrying this invention into effect involving minor variations, that it is not proposed to deal in the description with any but the more important ones.

In Figs. 4, 5 and 6 the source of applied high-frequency potentials is represented as an oscillatory circuit CS which may be any suitable part of a signalling system, although it need not necessarily be an oscillatory circuit.

Fig. 4 shows the use of two rectifiers V' and V^2 which are arranged to absorb or conduct alternate half-cycles of applied high-frequency current. The modulating potentials are supplied by M and vary the base-line potentials across the rectifier electrodes. A midway tapping is taken from the inductance S.

Fig. 5 shows another arrangement where two opposed rectifiers are connected across the oscillatory circuit. Each has a negative potential on its anode which is varied by a common microphone M.

Fig. 6 shows a modulation system in which the absorbing rectifier is connected across the grid and filament of an amplifier valve V^3 having an output system L. The high-frequency output of V^3 is modulated when speaking into M. Any of the arrangements shown or modifications of them may be used in a system of this kind where the modulated currents are amplified. Fig. 7 is another absorption circuit in which the modulated high-frequency current is amplified. In this and all the other circuits the original source of oscillations may conveniently be an oscillating valve system of some kind or other. The modulating potentials may, of course, be amplified in known manner when desired.

Fig. 8 is a modified arrangement of the invention. Where large currents are to be absorbed, instead of connecting the rectifiers in parallel in the ordinary way, it is preferred to connect them in parallel in such a way that their conductivity varies in succession. This may be accomplished by grading the negative potentials on their anodes substantially as shown in Fig. 8.

Resistances R′, R², R³ shunted by condensers may be inserted in each anode circuit.

The invention is applicable to all forms of signalling and for both transmission and reception where the varying absorption property of a rectifier is capable of utilization. For example when receiving continuous waves, the oscillations might be modulated at audible frequency according to this invention so as to render them audible after rectification.

Having thus described the nature of the said invention and the best means I know of carrying the same into practical effect, I claim:—

1. The method of modulating radio-frequency currents for wireless telephonic and like communication which comprises controlling the conductivity of a two-electrode rectifier to radio-frequency currents applied thereto by impressing low-frequency modulating currents on the anode voltage thereof and applying a steady negative potential thereto of a value which will substantially prevent the flow of radio-frequency currents while no modulating currents are impressed on the anode voltage.

2. In wireless signalling systems a current-absorbing device comprising a two-electrode rectifier shunted by an inductance traversed by high frequency oscillations, a source of steady negative potential of a value not greater than the amplitude of the said high frequency oscillations connected with the anode of the said rectifier, and means for applying low frequency modulating potentials to the said anode.

3. In wireless signalling systems, a current-absorbing device comprising a plurality of two-electrode rectifiers connected in parallel with each other and with an inductance traversed by radio-frequency currents, sources of steady negative potentials of graded values connected with the anodes of the said two-electrode rectifiers and microphonic means for varying simultaneously the potentials of the said anodes.

4. A high frequency telephone transmitter particularly for wireless telephony comprising an amplifier the output circuit of which is associated with an aerial and the input circuit of which is separately excited by a source of continuous oscillations, a two-electrode valve having a negative potential on its anode being connected in shunt with the input circuit, and means being provided for varying microphonically the potential on the anode of the two-electrode valve.

In testimony whereof I have signed my name to this specification.

JOHN SCOTT-TAGGART.

April 17, 1928. 1,666,676

B. G. BJÖRNSON

REPEATER CIRCUITS

Original Filed June 27, 1925

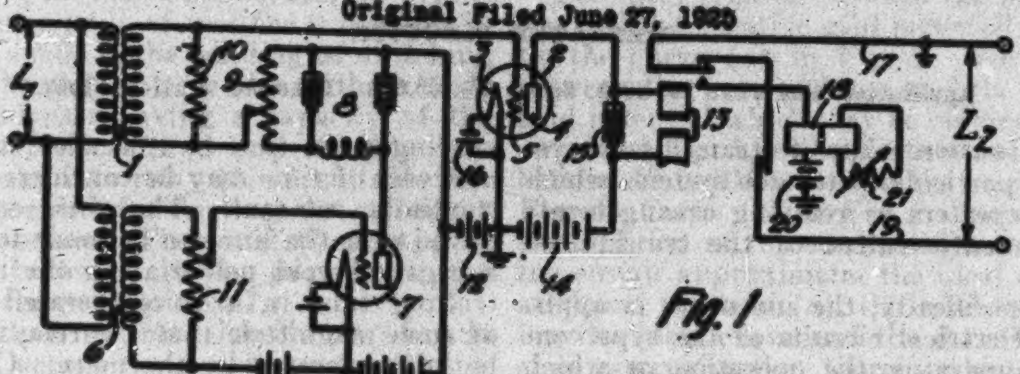


Fig. 1

Fig. 2

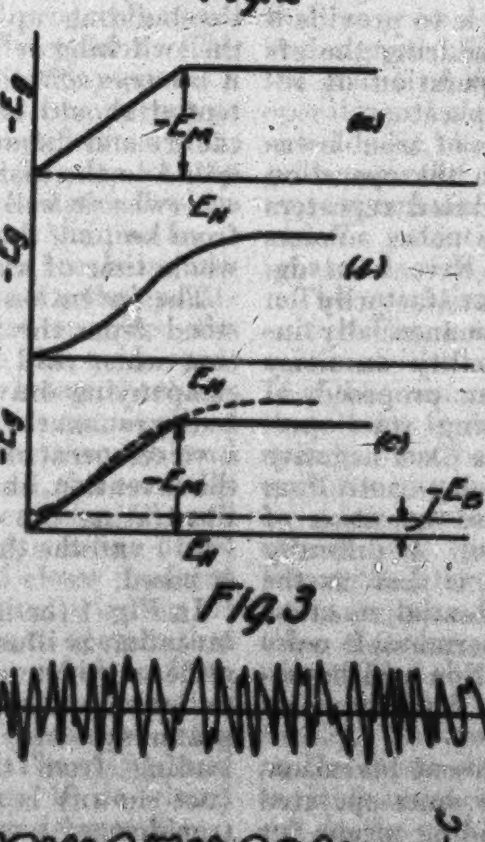
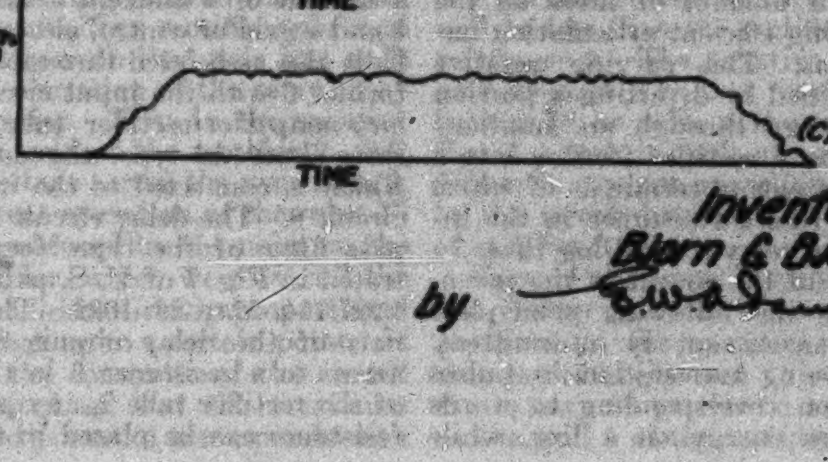


Fig. 3



Inventor:
Bjorn G. Björnson
by E. W. Adams Atty

Patented Apr. 17, 1928. 1,666,676

UNITED STATES PATENT OFFICE.

BJÖRN G. BJÖRNSON, OF NEW YORK, N. Y., ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

REPEATER CIRCUITS.

Application filed June 27, 1925, Serial No. 39,884. Renewed April 25, 1927.

This invention relates to transmission systems and particularly to such systems which include repeaters or relaying arrangements for the reenforcement of the transmitted energy.

More specifically, the invention is applicable to electrical circuits of the type containing apparatus, the operation of which is based on the transmission of short electrical impulses, such as voice-operated repeaters and the like.

An object of the invention is to provide a method of and means for reducing the effect of line noise on the operation of repeater circuits or similar apparatus.

One of the greatest sources of trouble encountered in connection with the operation of circuits such as voice-operated repeaters and the like is so-called line noise. Voice-controlled repeater circuits have been devised which operate very satisfactorily on quiet lines, but are either commercially inadequate or afford poor quality on noisy lines. It has heretofore been proposed, in connection with systems using voice-operated relay systems to utilize a fixed negative potential on the grid of a relay-controlling vacuum tube to prevent false operation of the relays due to line noise. A difficulty with such systems, however, is that, as the source of fixed negative potential must be adjusted for the maximum permissible noise on the system, poor articulation will be obtained as the noise decreases from its maximum value.

In accordance with the present invention, false operation of impulse or voice-operated relays is prevented by providing means for producing on the grid of a relay-controlling vacuum tube a negative potential varying in proportion to the amount of noise on the system, thus giving efficient articulation under all conditions. This varying negative potential is obtained by diverting a portion of the noise energy through an auxiliary circuit comprising a rectifier feeding into a delay circuit, the output terminals of which are connected across a resistance in the input circuit of the relay-controlling tube.

The operation of the circuit of the invention is based on the following principles: While voice transmission is intermittent, speech energy being transmitted in pulses of short duration corresponding to words spoken, the noise energy on a line, while varying from time to time, for such short intervals of time may be considered as substantially constant. The noise energy received over the line can be made to produce a negative grid potential on the relay-controlling tube in a voice-operated repeater of such magnitude that the relays will not be kept operated by the noise. Obviously, the speech received over the line will also produce a negative potential on the grid of the relay-controlling tube, but by delaying the building up of this negative potential the switching relays may be operated before it becomes effective. This negative grid potential should be proportional to the noise energy and its maximum value should correspond to the maximum permissible noise, as otherwise it will also finally prevent speech from keeping the relays operated during the whole time of a speech impulse.

The invention may be more fully understood from the following detailed description when read in connection with the accompanying drawing, in which Fig. 1 shows a diagrammatic illustration of a portion of a voice-operated repeater circuit embodying the invention, and Figs. 2 and 3 show curves illustrating the operation of the system of Fig. 1 and the theory on which the invention is based.

In Fig. 1 the noise protective device of the invention is illustrated as applied to an amplifier-rectifier circuit used for operating switching relays in a voice-operated repeater system. The section L_1 of the line leading from the voice-operated repeater (not shown) is associated through an input transformer 1 with the input circuit of the main amplifier-rectifier tube 2, which is of the well known three-electrode type having a cathode or a filament 3, an anode or plate 4 and a grid or control electrode 5. The line L_1 is also associated through an input transformer 6 with the input circuit of an auxiliary amplifier-rectifier tube 7, also of the three-electrode type, the output circuit of which is connected to the input of a delay circuit 8. The delay circuit 8 may be a low-pass filter of the type, for example, illustrated in Fig. 7 of U. S. patent to Campbell 1,227,114, May 22, 1922. The output terminals of the delay circuit 8 are connected across to a resistance 9 in the input circuit of the rectifier tube 2, any portion of which resistance can be placed in series in the in-

put circuit. Resistances 10 and 11 are connected across the input circuits of rectifiers 2 and 7, respectively.

The input circuit of rectifier 2 includes in series the cathode 3, the grid battery 12, the resistance 9, the resistance 10, and the grid 5. The output circuit of rectifier 2 includes in series the anode 4, the winding of switching relay 13, the plate battery 14, and the cathode 3. A condenser having a capacity of the order of 0.1 microfarad is preferably connected in shunt to relay 13. A suitable battery is provided for heating the cathode 3 to incandescence. The usual filament, grid and plate batteries are also provided in the circuit of the rectifier tube 7.

The leads from the delay circuit 8 are so connected across the resistance 9 with respect to the leads across the resistance 10 that energy from the line L_1 passing through the auxiliary circuit comprising the rectifier 7 and the delay circuit 8 will produce a negative potential on the grid of rectifier 2. The low-pass filter comprising the delay circuit 8 in the auxiliary circuit serves two purposes: (1) it produces a smooth rectified current; and (2) it delays the building up of the voltage across the variable resistance 9 when a speech pulse is received over the line L_1.

When no speech impulses are being received from the incoming line L_1, the operating winding of relay 13 is not energized, the outgoing line L_2 leading to the voice-operated repeater (not shown) being short-circuited. In this condition, the terminals of line L_2 are connected together through lead 17, the back contact of relay 13, the normally closed contact of a hangover relay 18, and lead 19. When the operating winding of relay 13 is energized, relay 13 closes its front contact, causing the operating winding of relay 18 to be energized so as to operate that relay, the energizing circuit extending from grounded battery 20, through the operating winding of relay 18, front contact of relay 13, and lead 17 to ground. The right-hand winding of hangover relay 18 is closed through a suitable variable resistance 21.

For an ideal condition from the standpoint of articulation, it is desirable that the magnitude of the negative potential on the grid 5 of the relay-controlling rectifier tube 2 at all times should be such that it is just sufficient to prevent operation of the relay 13 by the noise on the line. That is, the negative potential on the grid of the rectifier 2, and, therefore, the voltage across the resistance 9, required to prevent operation of the relay 13 by the voltage produced by the noise on the grid of the rectifier, which we may call the noise voltage, should be directly proportional to the noise voltage up to a certain point. It is obvious that the constants of the circuit should be adjusted so that the maximum value of this grid potential corresponds with the maximum permissible noise, as otherwise this negative potential would finally prevent speech from keeping the relay 13 operated during the whole time of a speech impulse.

The ideal relation between the noise voltage and the negative grid potential is shown by the curve (*a*) in Fig. 2. The relation between the noise voltage and the negative grid potential which may be obtained by the circuit of Fig. 1, without the use of the grid battery 12 is illustrated in the curve (*b*) of Fig. 2. Curve (*c*) of Fig. 2 illustrates how the addition of the small grid battery 12 to the circuit approximates the ideal condition as shown in curve (*a*), the solid line denoting the ideal curve and the dotted line the close approximation thereto which may be obtained by the circuit of Fig. 1 including the grid battery 12. In the curves (*a*), (*b*), and (*c*) of Fig. 2, the voltage produced by the line noise on the grid 5 of the rectifier 2 is designated E_N, the negative potential on the grid 5 of rectifier 2 required to prevent operation of the switching relay 13 is designated $-E_0$, the maximum value of negative grid potential corresponding to the maximum permissible noise is designated as $-E_m$, and the potential of grid battery 12 is designated as $-E_B$.

The operation of the noise protection circuit of Fig. 1 will now be explained in connection with the curves of Fig. 2 and Fig. 3. It will be assumed, for explanation purposes, that there is some noise on the line when speech is not being received. This noise energy for any small interval of time may be considered as constant. The noise energy received over the line L_1 divides, the part transmitted through the input transformer 1 being impressed on the input circuit of rectifier 2 across resistance 10, and the part transmitted through the input transformer 6 being rectified in the rectifier 7, transmitted through the low-pass filter 8, and impressed on the input circuit of rectifier 2 across the variable resistance 9. As the drop in potential in the variable resistance 9 opposes the drop in potential in the resistance 10, the resistances 9 and 11 may be so adjusted that the maximum voltage across resistance 10 will be less than the rectified voltage across resistance 9. The negative potential on the grid, then, will be that produced by the grid battery 12, or $-E_B$ as shown in curve (*c*) of Fig. 2, which is made of just sufficient magnitude to prevent operation of the relays 13 by the rectified energy in the output circuit of rectifier 2.

Now, if the noise energy on the line received over the line L_1 varies, the drop of potential in the variable resistance 9 will vary accordingly and in combination with the battery 12 produce a negative potential on the grid 5 of the rectifier 2 in accordance

with the dotted curve in Fig. 2 (c), this potential being of just sufficient magnitude to prevent the production by the noise of a current in the output circuit of tube 2 of sufficient magnitude to operate the relay 13.

Now, if an impulse of speech energy is received from the repeater circuit over the line L_1, the portion transmitted, together with part of the noise on the line, through transformer 1 and impressed on the input circuit of rectifier 2 across the resistance 10, causes the production of a voltage of such amplitude as to overcome the negative potential on the grid 5. A rectified current will be thereby produced in the output circuit of tube 2 of sufficient amplitude to operate relay 13, which in turn will cause the operation of the hang-over relay 18. The portion of the speech energy transmitted, together with part of the noise on the line, through the transformer 6, is rectified by the rectifier 7, transmitted through the delay circuit 8, and impressed on the input circuit of tube 2 across variable resistance 9. This energy will, of course, produce a negative potential on the grid 5 of rectifier 2 of sufficient magnitude to prevent operation of the relay 13, but the delay circuit 8 will delay the building up of this negative voltage so that the switching relay 13 will be operated by the speech energy in the main circuit before it becomes effective. The whole output voltage of input transformer, therefore, is available until the auxiliary circuit starts up to build a negative grid potential across the variable resistance 9.

The time of operation of the relay 13 varies from syllable to syllable, and if there is no noise protecting negative grid potential, it might be anywhere from .002 to .02 of a second. As the delay in the circuit may be made greater than .02 of a second, the speed of operation of the circuit will be about the same as if the circuit were adjusted for a quiet line. The building up of the voltage across the resistance 9 should be delayed by the delay circuit 8 for such a length of time that the voltage produced by the voice currents across resistance 10 at that time shall have risen to a higher voltage than the maximum across resistance 9. When the maximum negative grid potential produced by the speech and noise transmitted through the auxiliary circuit becomes effective, the input voltage to the rectifier 2 will be decreased. This decrease in voltage, however, will not be sufficient to cause relay 13 to release, as at that time the voltage produced by speech across resistance 10 will be greater than the saturation voltage across resistance 9 and also only a small current is needed to keep relay 13 operated although a relatively large one is needed to operate it quickly.

The action of the circuit of Fig. 1 for one word or syllable is illustrated in Fig. 3, curve (a) of that figure showing the variation with time of the electrical energy representing a word or impulse, curve (b) the corresponding variation with time produced thereby in the rectified current in relay 13, and curve (c) the corresponding variation with time in the negative potential produced by the speech impulse on the grid of the rectifier tube 2. In these curves, the ordinates represent electrical energy, voltage or current, and the abscissas time.

Referring to the curves, it will be noted that when the speech impulse is received, the current in the relay winding 13 starts to increase at once and will be of sufficient amplitude to operate this relay at some time A before the auxiliary circuit, comprising the rectifier 7 and the delay circuit 8, begins to build up negative potential on the grid of rectifier 2. The operation of the relay 13 causes the operation of the hangover relay 18 at a slightly later time, indicated by B in the curves. At some time C near the end of the speech impulse, the rectified current in the relay winding 13 will decrease sufficiently, due to the building up of the negative potential on the grid 5 of rectifier 2, so that relay 13 releases. The release of relay 13 will also cause the release of hang-over relay 18. Variable resistance 21 is adjusted so that the time of relaxation of this relay is such that its release occurs at but a slightly later time D after the end of the speech impulse, thus preventing part of the word from being cut off.

It is desirable to design the delay circuit 8 so that it will first give an absolute delay and then a quick rise of the negative voltage on the grid 5 of rectifier 2. If the time of rise of this voltage is too long, the circuit may be sluggish in adjusting itself to variations in the noise received over the line L_1. Also, at the end of a word, the time interval that has to be considered is the absolute time delay plus the time of decay of the negative potential on the grid 5 of rectifier 2. This time interval should be shorter than the time of relaxation of the relays 13 and 18, as otherwise a syllable might find the negative potential produced by the preceding syllable still effective on the grid of rectifier 2. This condition may be prevented by making the time of relaxation of the hang-over relay 18 long enough to take care of this delay.

It is, of course, quite obvious that the noise received over the line L_1 may increase very suddenly. The circuit would then be inoperable in one direction for a short interval corresponding to the time delay in the auxiliary circuit comprising the rectifier 7 and the delay circuit 8. If the noise variation happens during conversation over the circuit, it can only do harm if it is on the

listener's side of the repeater, and only then if it happens between syllables when the circuit is in neutral position. The interval of time in which the circuit would be biased by the noise against the talker would in practically every case be smaller than the time delay in the auxiliary circuit. This time delay can be made small enough so that it interferes very slightly and will not even be noticed in an ordinary conversation.

The advantage of the noise protection circuit of Fig. 1 over any circuit utilizing a fixed negative grid potential for noise protection is quite marked. As stated before, if a fixed negative grid battery is used it will have to be adjusted for the maximum permissible noise on a line. Under these conditions the articulation will get worse as the noise decreases from its maximum value due to the longer switching time required, or, in other words, the articulation will be best when the maximum permissible noise is on the line and worse when there is no noise on the line. The noise protection circuit of the invention, however, produces a negative potential at all times, which is just sufficient to neutralize the effect of the line noise.

The circuit of the invention is particularly suitable for protecting voice-operated repeaters of both the neutral and biased types against noise, but it is not limited to voice-operated repeaters, but may be applied for noise protection in any circuits containing apparatus, the operation of which is based on the transmission of short impulses of energy. The system illustrated in the drawing and described above should be construed merely as typical and not as limiting the invention, the scope of which is defined in the appended claims.

What is claimed is:

1. The method of discriminating between momentary impulses of current and relatively steady disturbing currents received over a circuit in their effect on a receiver circuit, comprising utilizing part of the received energy to operate the receiver circuit, separately utilizing part of the received energy to bias said receiver circuit against operation, continuously neutralizing the operating energy due to said steady disturbing currents with the biasing energy due to said disturbing currents, and delaying the effect on said receiver circuit of the biasing energy due to said momentary impulses with respect to the effect on said receiver circuit of the operating energy due to said momentary impulses, thereby insuring operation of said receiver circuit by said momentary impulses.

2. In a transmission system, a path over which momentary impulses of current are transmitted and subject to relatively steady disturbing currents, a receiver circuit, means to utilize part of the energy received over said path to operate said receiver circuit, means to separately utilize part of the received energy to bias said receiver circuit against operation, means to continuously neutralize the effect on said receiver circuit of the operating energy due to said disturbing currents with the biasing energy due to said disturbing currents and means to delay the effect on said receiver circuit of the biasing energy due to said momentary impulses with respect to the effect on said receiver circuit of the operating energy by an interval sufficient to enable operation of said receiver circuit by said momentary impulses.

3. In a signaling system, a space discharge repeater, input and output circuits therefor, a current responsive device in said output circuit, a line connected to said input circuit over which waves of rapidly varying amplitude are transmitted and subject to disturbing waves of slowly varying amplitude, means for neutralizing the effect of said slowly varying waves on said input circuit, and means for causing said rapidly varying waves to control the operation of said current responsive device.

4. In combination, a line over which momentary impulses of current are transmitted, and subject to relatively steady disturbing current, a receiver element responsive to said energy impulses, an electron discharge device fed by said line and feeding said receiver element, said electron discharge device including a control electrode, means to produce on said control electrode a negative potential varying in accordance with said disturbing currents and of sufficient magnitude to prevent disturbing variations from being propagated through said device, the magnitude of said negative potential being insufficient to prevent said momentary impulses from said line from being propagated through said device to said receiver element.

5. In a transmission system, a circuit over which momentary impulses of energy are transmitted and subject to relatively steady disturbing variations, an electron discharge device fed by said circuit, said electron discharge device comprising a control electrode, a receiver element controlled by waves transmitted through said device, means to produce on said control electrode a negative potential varying in accordance with said disturbing variations, such as to prevent the transmission through said device of disturbing variations of sufficient amplitude to effect the operation of said receiver element, and means to delay the building up of a negative potential on said control element by one of said momentary impulses until after said device has been operated to repeat said one impulse.

6. In a signaling system, a line over which

energy comprising momentary impulses of current and relatively steady disturbing variations is transmitted, an electron discharge device fed by said line, said electron discharge device having a control electrode, a receiver element responsive to wave transmitted through said device, means to cause the energy received from said line to produce on said control electrode a negative biasing potential varying in accordance with said disturbing variations and at all times of sufficient magnitude to prevent said disturbing variations from being transmitted through said device, and means to delay the production on said control electrode of a negative potential by one of said momentary impulses until after said one impulse has been propagated through said device.

7. In combination, a line over which momentary impulses of current are transmitted and subject to relatively sustained disturbing currents, an electron discharge device comprising an input and an output circuit, a receiver element in said output circuit responsive to waves transmitted through said device, means to impress part of the energy received over said line on said input circuit in a sense to render said device operative to transmit, separate means to impress part of the energy received over said line on said input circuit in a sense so as to bias said device against operation, said separate means being adjusted with respect to the first mentioned means so that the resultant effect of said sustained disturbing currents is at all times such as to prevent the operation of said discharge device by said sustained currents, and means to delay the transmission to said input circuit of the biasing energy due to one of said momentary impulses with respect to the operating energy due thereto until said one impulse has been transmitted through said device.

8. In combination, a space discharge repeater having input and output circuits, a receiving device in said output circuit, a plurality of resistances in said input circuit, a source of waves having impulse components representing speech and relatively steady components representing noise, separate paths connecting said source to said resistances whereby the drop in potential produced by noise components in one of said resistances neutralizes the drop in potential produced by noise components in the other of said resistances, and means included between said source and said input circuit for causing the potential drop produced by speech components in one of said resistances to be different from the drop in potential produced by speech components in the other of said resistances so that speech components only are transmitted through said repeater to said receiving device.

9. In combination, a space discharge device, an input and an output circuit therefor, two resistances in series in said input circuit, a source of complex waves including impulsive and steady components, a receiving element in said output circuit and responsive to said waves, means comprising a path connecting said source in shunt to one of said resistances to cause the production in said one resistance of a drop in potential corresponding to a portion of said complex wave at a certain instant, a separate path connecting said source in shunt to the other of said resistances, and means in said separate path comprising a delay circuit to cause the production in said other resistance at the same instant of a drop in potential corresponding to a portion of said complex wave at a different instant, the resulting difference in potential on said input circuit causing waves from said source to be transmitted through said device to said receiving element.

10. In combination, a line over which speech impulses are transmitted, and subject to steady disturbing currents, a space discharge device having an anode, a cathode and a control electrode, a receiver element connected between said anode and cathode, and responsive to energy variations transmitted through said device, two resistances and a battery connected in series between said cathode and said control electrode, a path connecting said line in shunt to one of said resistances, a separate path connecting said line in shunt to the other of said resistances, said separate path comprising a space discharge device and a delay circuit.

11. In combination, a line over which momentary impulses of current are transmitted, and subject to steady disturbing currents, a space discharge device comprising an input and an output circuit and having a control electrode, a receiver element in said output circuit responsive to current variations transmitted through said space discharge device, two resistances in series in said input circuit, a path connecting said line in shunt to one of said resistances, whereby a drop in potential proportional to energy received over said line is produced in said resistance, a separate path comprising a second space discharge device connecting said line in shunt to the other of said resistances whereby a drop in potential proportional to energy received over said line is produced in said other resistance opposing that produced in the first mentioned resistance, said resistances being so proportioned with respect to each other that a resultant negative potential varying in accordance with said disturbing current variations is maintained on said control electrode by said steady disturbing currents of such magnitude as to prevent said device from becoming operative to propagate said disturbing

variations therethrough but of insufficient magnitude to prevent operation of said device by said momentary impulses transmitted over the first mentioned path, and means in said separate path to delay the building up of a negative blocking potential on said control electrode by said momentary impulses of current transmitted over said separate path.

12. In a voice-operated relay circuit, a path over which fluctuating voice currents and relatively sustained alternating currents may be transmitted, a space discharge device fed by said path and having a control electrode, means to produce on said control electrode a continuous negative potential varying in accordance with said sustained currents and at all times of sufficient magnitude to prevent operation of said space discharge device by said sustained currents, and means to insure operation of said space discharge device by said voice currents.

In witness whereof, I hereunto subscribe my name this 23 day of June A. D., 1925.

BJÖRN G. BJÖRNSON.

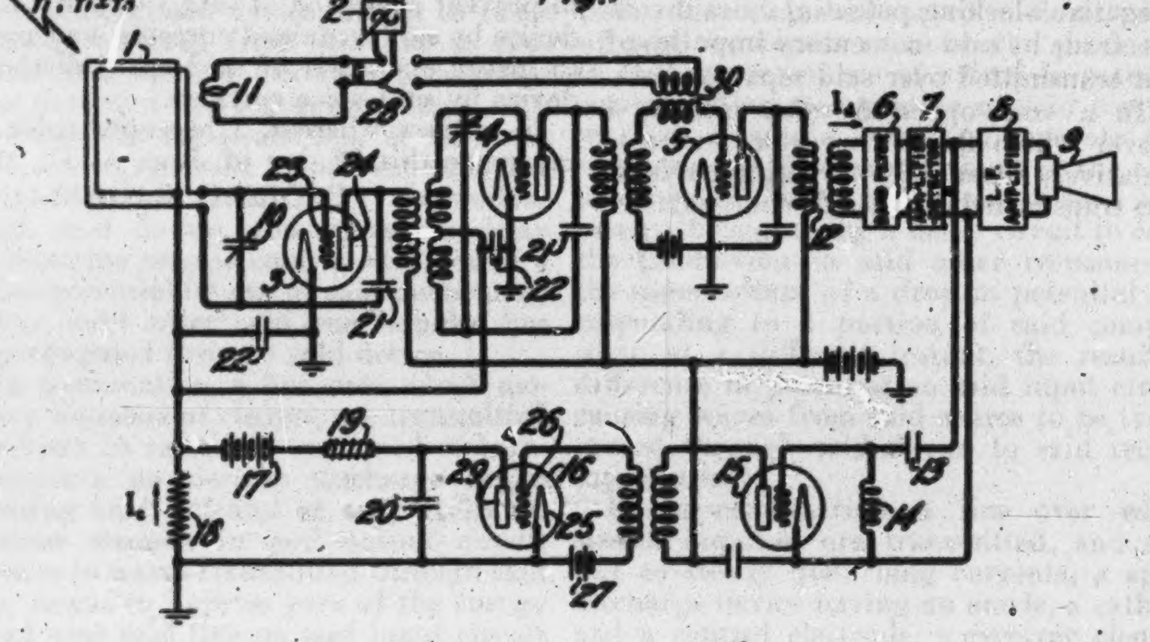
July 3, 1928. **1,675,848**

H. T. FRIIS

TRANSMISSION REGULATION

Filed Nov. 29, 1924

Fig.1



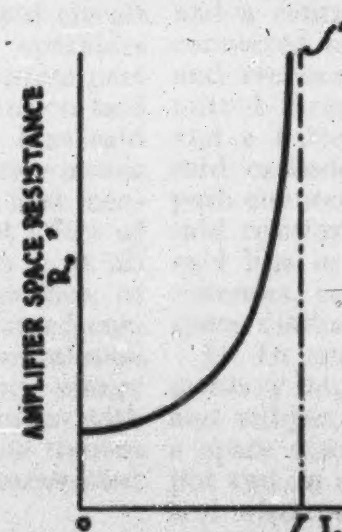
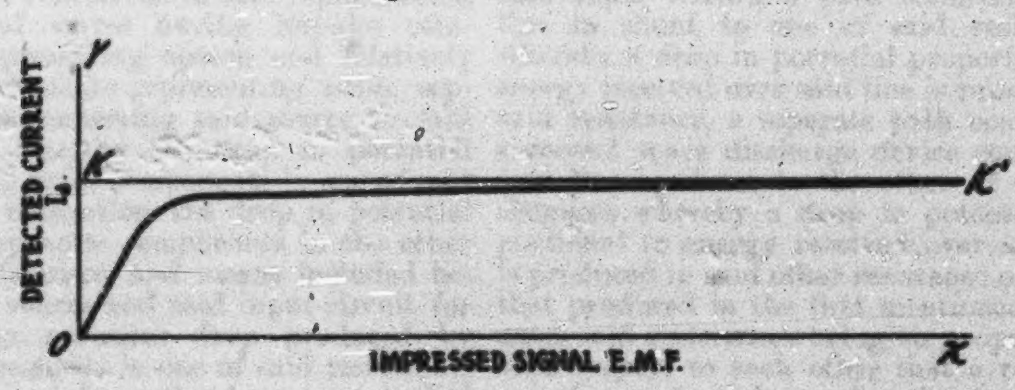


Fig.2

Fig.3



Inventor:
Harald T. Friis
by Atty.

Patented July 3, 1928. 1,675,848

UNITED STATES PATENT OFFICE.

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TRANSMISSION REGULATION.

Application filed November 29, 1924. Serial No. 752,891.

This invention relates to radio receiving systems and more particularly to methods of and means for controlling the intensity of received signals at a uniform level.

One object of the invention is to improve the constancy of the over-all transmission equivalent in radio communication systems.

It is well known that radio signaling waves are subject to extremely variable attenuation and that the strength of the received signals may vary so greatly as to make it difficult and even impossible at times to obtain satisfactory communication. These variations may be due to the regular changes between day and night conditions or they may be the much more rapid changes which are commonly known as "fading" effects. Slow changes of the former kind may be compensated by manual adjustment of the sensitivity of the receiving system, but compensation of the much more rapid fading effects requires some form of automatic adjustment.

To maintain a uniform transmission equivalent in a radio system it is necessary that any change in the attenuation of the medium be immediately offset by an opposite change in the gain characteristic of the receiving system. Methods of securing this result have been proposed by Espenschied and Bown in U. S. Patent No. 1,447,773, issued March 6, 1923, and by Affel in U. S. Patent No. 1,468,687, issued September 25, 1923.

The methods disclosed in these patents consist in radiating along with the signal wave a "pilot" wave of constant amplitude, and employing at the receiving station currents corresponding to this wave to control the sensitivity of the receiving system. The control apparatus, including mechanical elements, is so arranged that if the received pilot wave diminishes in intensity the sensitivity of the receiving system is increased by a corresponding amount and vice versa.

The pilot wave, being free from signal variations, is modified only by the attenuation of the transmission medium and therefore the control of the receiver gain is responsive only to changes in the attenuation of the medium. In most communication systems the signal is transmitted as a modulated carrier wave, which may be considered as a wave of single frequency and varying amplitude or alternatively as a group of waves including a constant wave of the carrier frequency and side waves representing the signal. It is therefore unnecessary to provide a special pilot wave as the carrier wave, when separated from the side waves, is satisfactory for the purpose. A transmitting system suitable for this method of transmission is described in U. S. Patent No. 1,442,147, January 16, 1923, to Heising.

By the present invention an improved means is provided for controlling the sensitivity of the receiving system in accordance with the intensity of the received carrier or pilot wave. The control is effected without the intervention of any mechanical device and may be made to respond accurately to and to compensate changes in the transmitting medium having periods of less than one fiftieth of a second.

In the detailed description which follows the invention will be described as applied to radio telephony for the reason that the need is greatest in that field. It is to be understood, however, that it may be applied equally well to any type of carrier wave system regardless of the nature of the medium of transmission.

Fig. 1 of the drawings shows a receiving system in which the invention is embodied;

Fig. 2 shows a special characteristic curve for an amplifier which is adapted to illustrate the operation of the invention; and

Fig. 3 is the operating characteristic curve of the receiving system of Fig. 1.

The receiving system of Fig. 1 is of the double detection or super-heterodyne type in which an intermediate frequency carrier wave is produced by demodulation of the incoming wave with an auxiliary wave locally generated. The incoming waves are received by the loop antenna 1 which may be tuned to resonance by means of condenser 10. The auxiliary wave is supplied from a local source 2 and is impressed upon the

high frequency circuit through a small loop 11 which is coupled to the receiving loop 1. Two stages of high frequency amplification are provided by the tandem connected space discharge amplifiers 3 and 4, both the incoming waves and the auxiliary waves being amplified thereby. The first stage of detection occurs in the space discharge demodulator 5 from the output of which the demodulation products are delivered through a transformer 12 to the band-pass filter 6.

The function of filter 6 is to separate out and transmit only the intermediate frequency waves corresponding to the difference between the incoming wave frequencies and the auxiliary wave frequency. It is preferable that the intermediate frequency waves should occupy a band centered in the neighborhood of 50,000 cycles per second, the width of the band being made sufficient to include the intermediate frequency carrier and all side frequencies necessary for the proper reproduction of the signal. The filter may be constructed in accordance with the methods and formulæ disclosed in U. S. Patent No. 1,227,113, issued May 22, 1917, to G. A. Campbell.

The selected intermediate frequency band is amplified in the amplifier-detector 7, in which the final step of detection to produce the low frequency signal currents also takes place. The low frequency currents are delivered to an amplifier 8 and the amplified current is supplied to the signal reproducer 9, which is illustrated as a loud speaking telephone.

The amplifier-detector 7 and the amplifier 8 are indicated only in conventional form, the particular type and arrangement used being unimportant, since any well known devices adapted to perform the desired functions may be used.

The local auxiliary wave source 2 should be adjustable so that the frequency of the intermediate carrier wave and the associated side frequencies may be within the range selected by the filter 6. A suitable form of auxiliary source is the space discharge oscillator disclosed in U. S. Patent No. 1,356,763, issued October 26, 1920 to R. V. L. Hartley.

The control current by which the sensitivity of the receiver is regulated is selected from the output of the amplifier-detector 7 by the resonant circuit 13, 14, connected in shunt to its output circuit, which is tuned to the frequency of the intermediate carrier wave. Its voltage after being amplified in the space discharge amplifier 15 is impressed upon the space discharge detector 16 in the output of which it produces a steady direct current. The control electrode 26 of the detector is so polarized by the battery 27 that little or no space current flows normally; consequently in accordance with the well known characteristics of space discharge detectors, an alternating E. M. F. impressed upon the control electrode produces a direct current in the space path which increases as the impressed E. M. F. increases.

The output circuit of the detector 16 includes the space discharge path between the anode 29 and the cathode 25, a separate space current source 17 and a fixed resistance 18. The cathode and one terminal of the resistance 18 are connected together at ground potential. Choke coil 19 and condenser 20 serve to prevent the flow in resistance 18 of any alternating current corresponding to the impressed intermediate frequency wave.

For reasons that will be explained later, the high frequency amplifiers 3 and 4 are provided with balancing capacities 21 to neutralize the coupling between the output and the input circuits of the amplifiers due to the internal electrode capacities.

In the first high frequency amplifier, the cathode is connected through a relatively large capacity 22 to the mid-point of the receiving loop, the potentials of the end terminals of which are therefore balanced with respect to the cathode and are of opposite sign. One terminal of the loop is connected to the input or control electrode 23 of the amplifier and the other is connected through the balancing condenser 21 to the anode 24. The capacity of the condenser 21 is substantially equal to the direct capacity between the electrodes 23 and 24. By this means, any current that might be transmitted directly from the input to the output of the amplifier through the electrode capacity is neutralized by an equal and opposite current transmitted through the balancing condenser.

The circuit of the second stage is similar and operates in a similar manner. The system of neutralization described has been disclosed in U. S. Patent No. 1,334,118, issued March 16, 1920 to C. W. Rice.

The control of the sensitivity of the system is secured by causing the rectified output current of the detector 16 to modify the control electrode potentials of the amplifiers 3 and 4. The cathodes of these amplifiers are connected to ground, and the control electrodes are connected to the ungrounded terminal of resistance 18, whereby they are caused to assume the potential of this point. This potential is determined by the current flowing in the resistance.

As current can flow only in the direction from ground to the anode of the detector 16, the fall of potential across the resistance 18 is such as to impress a negative potential

upon the amplifier control electrodes. An increase of the current in the resistances 18 will increase the negative potential applied to the control electrodes of the amplifier and in consequence will reduce the amplifier space currents. This is equivalent to increasing the internal resistance of the amplifiers and is effectual in reducing their over-all amplification. It follows then that an increase in the intensity of the incoming wave, by producing an intermediate frequency carrier wave of larger amplitude, causes an increased current to flow in the resistance 18, and thereby reduces the sensitivity of the receiving system.

The relationship between the space path impedances of the amplifiers 3 and 4 and the polarizing potentials of their control electrodes is shown qualitatively by the curve in Fig. 2. The ordinates are proportional to the space path impedance; the abscissæ are proportional to the steady current I_c flowing in the resistance 18, and therefore to the polarizing potentials applied to the control electrodes of the amplifier. The vertical dotted line JJ′ corresponds to the potential that is just sufficient to reduce the space current to zero, the space path impedance becoming infinite under this condition.

The detected current I_c cannot exceed the value corresponding to the abscissa OJ; since it requires for its production that some part of the incoming wave be repeated by the amplifiers and this cannot take place if the amplifiers are blocked. A continually increasing intensity of the incoming wave may cause the detected current to approach indefinitely close to the limiting value, but it can never attain such a value that the amplification of waves by the amplifier is actually stopped. The detected current will therefore be substantially constant for all intensities of the incoming wave greater than some low value depending on the initial sensitivity of the system. Since the detected current remains constant, it follows that the intermediate frequency carrier wave from which it is produced must also remain constant.

The relationship between the current intensity of the intermediate frequency carrier wave and the E. M. F. of the incoming signal carrier wave is shown by the curve of Fig. 3. The abscissæ are proportional to the E. M. F. of the incoming carrier wave measured at the input terminals of the amplifier 3, and the ordinates are proportional to the current intensity denoted by I_o of the intermediate frequency carrier wave at the point where it enters the band filter.

The horizontal line K, K′ represents the limiting value that the current I_o may approach but which it cannot equal or exceed. The ordinate OK is proportional to the intensity that produces the limiting value OJ in Fig. 2, of the control current I_c. The slope of the curve at the origin of the coordinates is proportional to the initial sensitivity of the system; namely the sensitivity that would be obtained if the control system were made inoperative, or the sensitivity that is obtained for such low intensities of the incoming wave that the effect of the control is negligible. Obviously, as the initial sensitivity of the system is increased, the control system will be operative to effect regulation at lower and lower intensities of the incoming waves.

The uniformity of the intermediate frequency carrier wave resulting from this method of control, corresponds to transmission through a medium of constant attenuation; the sound waves of the impressed message are reproduced with a strength that faithfully follows their original intensity regardless of the variations to which radio waves are subject in the medium.

It should be noted that the control affects only those waves that are repeated by the controlled amplifiers in the normal manner; it is not effective upon such portion of the waves that may be transmitted directly through the capacities of the amplifier electrodes.

Strong incoming waves might, under certain conditions, cause sufficient current to be transmitted through the amplified capacities to cause the control current I_c to reach and exceed the limiting value at which the amplifiers become blocked. Stronger wave intensities would then be uncontrolled, the amplifiers operating merely as fixed capacity networks to produce a fixed attenuation of the waves. By neutralizing the coupling between the input and the output circuits of the controlled amplifiers in the manner hereinbefore described, the direct transmission of the incoming wave is largely prevented and the range of intensities that can be controlled is greatly increased.

The use of two controlled amplifiers in tandem further increases the range that can be controlled by increasing the attenuation to which directly transmitted waves are subjected. Satisfactory control may, however, be obtained over a wide range of intensities using only one controlled amplifier.

An additional feature of the system described above that tends to increase the operating range of intensities, is the arrangement whereby the auxiliary wave from the local source is subjected to the action of the controlled amplifiers. As the intensity of the incoming wave increases and, through the action of the control circuit, reduces the effective amplification of the amplifiers, the strength of the auxiliary wave E. M. F. impressed upon the detector 5 is reduced.

Hence the intermediate frequency carrier approaches the limiting value at a slower rate than it would if the auxiliary wave were not controlled, and further, the component of the intermediate carrier due to the incoming wave is very small. Both of these factors are effective in extending the operating range.

With this arrangement, the demodulation of strong incoming waves in the detector 5 takes place with a considerably weakened auxiliary wave. Such a condition may give rise to a larger number of harmonics and other undesired modulation products, but these are suppressed by the band filter 6.

An alternative arrangement of the circuit may be used in which the auxiliary wave is impressed directly upon the demodulator 5 and is therefore not subject to the action of the controlled amplifiers. To permit the use of this arrangement, a switch 28 is provided by which the local source 2 may be connected to a coupling transformer 30, the secondary of which is connected in series with the input circuit of the demodulator. With this arrangement, constant conditions in the demodulator are obtained since the incoming wave is maintained at substantially constant intensity by the control current.

The response of the control to changes in the strength of the incoming wave is exceedingly rapid; that it is not instantaneous is due only to the presence of the condensers 22 and 20 which are connected in parallel with the resistance 18. The condensers 22 are inserted to provide a low impedance connection for the high frequency waves between the cathodes and the tuning coils in the amplifier input circuits. The condenser 20 is provided to absorb the alternating current in the output of the detector 16. They are effective in reducing the rapidity of response because they require a certain small time to charge or discharge when the applied potential is changed. It is found that the total capacity may be as great as 1 mfd. without increasing the response time above one-fiftieth of a second.

In experimental tests with a system of the type described but having only one controlled amplifier, received signals have been maintained constant in strength within 10% while the impressed wave intensities varied from a minimum to a maximum value one thousand times greater.

The operation of the invention has been described in connection with a double detection system, but it is obvious that the principles involved may be applied to the control of receiving systems in which no auxiliary wave is used and which employ only one demodulation of the incoming waves. Instead of an intermediate frequency carrier wave, the carrier component of the incoming waves would be selected to produce the control current, the selection, as in the system described, being made after the wave has passed through the controlled amplifier. The use of the double detection system, however, by establishing an intermediate carrier wave of relatively low frequency, makes it possible to separate the carrier more completely from its accompanying side frequencies and thereby to secure more exact regulation.

What is claimed is:

1. In a wave receiving system of the type in which an incoming carrier wave is demodulated with a locally generated heterodyne wave to produce a beat wave of a different frequency, a high frequency amplifier adapted to amplify both the incoming carrier wave and the heterodyne wave before demodulation, demodulating means, a rectifier adapted to produce a direct current from the beat wave, and means for controlling the efficiency of said amplifier in accordance with the strength of the rectified current whereby the intensity of the heterodyne wave applied to said demodulating means is diminished as the intensity of the incoming wave increases.

2. In a wave receiving system of the type in which an incoming carrier wave is demodulated with a locally generated heterodyne wave to produce a beat wave of a different frequency, means comprising a three electrode space discharge amplifier for amplifying both the incoming wave and the heterodyne wave before demodulation, demodulating means adapted to receive the amplified waves from said amplifier, a rectifying device for rectifying the beat waves produced by said demodulator and means for impressing the potential of the rectified current upon the control electrode of said amplifier, whereby the resistance of the space discharge path is increased in accordance with the intensity of the incoming wave.

3. In a heterodyne receiving system in which a space discharge amplifier is adapted to amplify the incoming waves and the heterodyne waves before detection, the method of controlling the sensitivity which comprises rectifying the waves of the beat frequency, and applying the rectified waves to reduce the efficiency of amplification of the incoming and the heterodyne waves.

4. In a heterodyne receiving system, a space discharge amplifier adapted to amplify the incoming waves and the heterodyne waves before detection, means for rectifying the waves of a beat frequency produced by detection and means for impressing the direct current potential of the rectified waves upon said amplifier to reduce its efficiency.

5. In a heterodyne receiving system, a method of controlling the volume of the detected signals which comprises simultaneously amplifying the incoming wave and the

heterodyne wave, and controlling the degree of amplification in an inverse manner as the amplitude of the received wave varies.

6. In a heterodyne receiving system, the method of controlling the volume of the detected signals which comprises amplifying the heterodyne wave prior to the step of detection, and varying the degree of amplification in an opposite sense to and in synchronism with variations of the intensity of the received wave.

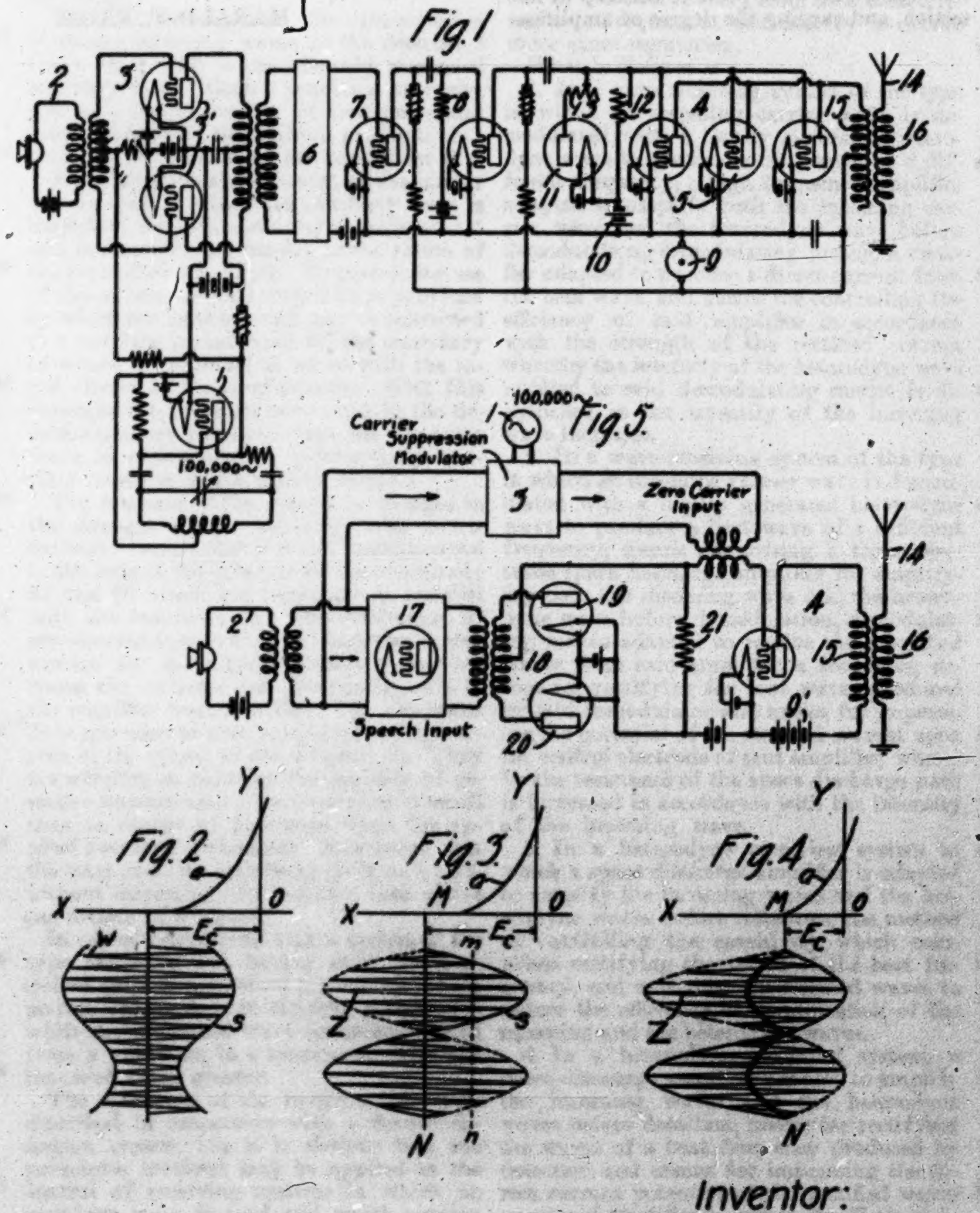
In witness whereof, I hereunto subscribe my name this 28th day of November, A. D. 1924.

HARALD T. FRIIS.

Oct. 9, 1928. **R. A. HEISING** 1,687,245

AMPLIFYING

Filed Dec. 30, 1922



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Patented Oct. 9, 1928. 1,687,245

UNITED STATES PATENT OFFICE.

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AMPLIFYING.

Application filed December 30, 1922. Serial No. 609,932.

This invention relates to the amplification of modulated waves and more particularly to the amplification of modulated high frequency waves for radio transmission.

It is well known how high frequency waves may be modulated in accordance with speech or other signals to produce a modulated wave from which the unmodulated carrier component is suppressed or how the unmodulated carrier component may be suppressed after modulation. Such a modulated wave with the unmodulated component of carrier frequency suppressed is often referred to as a "pure modulated wave." Oftentimes, for one reason or another, one of the side bands or side frequencies resulting from modulation is also suppressed, and the remaining wave is then referred to as a single side frequency without unmodulated carrier. In the present specification, any modulated wave from which the unmodulated carrier frequency component has been entirely or largely suppressed will be referred to as a "zero carrier modulated wave" or "zero carrier wave." This definition is intended to include a wave wherein both side frequencies are present or wherein only one side frequency is present.

A difficulty present in amplifier systems in general and especially important in amplifier systems for amplifying considerable power, as in radio transmission, is the inefficiency of vacuum tubes when used as amplifiers. For efficiency a high negative voltage must be impressed upon the grid and considerable distortion occurs. In a system heretofore devised and used by applicant, this difficulty is surmounted by operating the tube at such a point on its characteristic as to amplify the modulated portion only of an incompletely modulated wave.

In order to use vacuum tube amplifiers of high efficiency for amplifying "zero carrier" waves, other difficulties which arise must be overcome. These difficulties and the method of surmounting them will be discussed hereinafter.

One system described herein for exemplifying the invention consists of an arrangement in which zero carrier modulated waves are supplied to a space discharge amplifier of the usual type having an anode-cathode output circuit and a grid-cathode input circuit. The grid is adjusted to a negative potential such that space current just begins to flow when no waves to be amplified are applied to the input circuit. A rectifier is connected across the input circuit in such a manner that the application of waves to be amplified to the input circuit causes the grid to become more negative as the amplitude of the applied waves becomes larger. The system operates without appreciable loss of the signaling frequency components by which the carrier wave is modulated and is highly efficient.

In another system, current of the modulating wave form is rectified and applied to the input circuit of the power amplifier to cause the grid potential thereof to become more negative as the amplitude of the applied waves becomes larger and vice versa, to cause the grid potential to become less negative as the amplitude of the applied waves becomes smaller.

It is an object of this invention to amplify zero carrier waves by vacuum tube amplifier systems working at high efficiency. In this specification, the expression "high efficiency" is used to describe the condition of operation in which the ratio of the energy of the desired wave form produced in the output circuit to the total energy supplied to the amplifier system is high.

The novel features believed to be characteristic of the invention are set forth with particularity in the appended claims. The invention itself, however, both as to organization and method of operation, together with further objects and advantages thereof will best be understood from the following detailed description taken in connection with the accompanying drawings wherein Fig. 1 is a circuit diagram of a system for amplifying zero carrier waves with high efficiency; Fig. 2 is a diagram illustrating high efficiency amplification of ordinary modulated waves by a vacuum tube amplifier system; Fig. 3 is a diagram illustrating the inapplicability of the method illustrated in Fig. 2 to zero carrier modulated waves; Fig. 4 is a diagram indicating the mode of operation by which the amplifier system illustrated in Fig. 1 overcomes the disadvantages indicated by the diagram of Fig. 3; and Fig. 5 illustrates a modified form of system for amplifying zero carrier modulated waves.

In Fig. 2, the curve *a* represents the grid-

voltage-plate-current characteristic of a vacuum tube amplifier in which grid voltages are plotted along the axis OX and plate currents are plotted along the axis OY. The value of E_c represents the normal negative grid voltage to be used when the amplifier functions to amplify an incompletely modulated high frequency wave represented by the curve *w*, this wave being modulated in accordance with a speech frequency wave *s*. When the wave *w* is applied to the input circuit of the amplifier the grid voltage will at times during each high frequency cycle become of such value that space current will flow in the output circuit. This will result in the production in the output circuit of a substantially completely modulated high frequency wave of slightly distorted wave form. For radio transmission the distortion introduced is a disadvantage, but not such a disadvantage as to overcome the advantage inherent in this method of amplification.

A consideration of the wave form of the high frequency modulated wave applied to the grid circuit in accordance with Fig. 2 as compared with the wave form of a zero carrier modulated wave indicates at once that the method of Fig. 2 is inapplicable for the amplification of zero carrier modulated waves, inasmuch as the wave form of the latter is such that the envelope of the high frequency wave which represents the wave form of modulating wave is constantly descending to and crossing and recrossing the zero axis. Thus in Fig. 3 the curve *s* represents a zero carrier modulated wave consisting of both side bands and *s* represents the modulating wave. It appears at once that any system of amplifying in which only the higher peaks of the wave *s* are amplified will result in a loss of important signaling components. Thus, for example, it would not be desirable to amplify only those portions of the wave indicated as lying to the right of the dotted line *mn*. Furthermore, if all portions of the wave lying to the right of the central axis MN are amplified, the system will be inefficient from the standpoint of power consumption.

Consider now the mode of operation indicated in Fig. 4. In this case the normal negative grid voltage E_c is adjusted to that point where space current just begins to flow instead of being set well below the point at which space current begins to flow as in the case of Fig. 2. This results in good amplification of those portions of the zero carrier modulated wave of small amplitude. If now the negative grid voltage is caused to become considerably more negative during those portions of the speech frequency cycle when the zero carrier wave is of large amplitude, efficiency of operation and absence of signal destroying distortion will both result. In order to accomplish this, the negative grid voltage E_c is caused to vary in accordance with the heavy curve MN as indicated in Fig. 4. The wave form of the curve MN suggests at once that it is periodic and that its fundamental frequency is twice that of the signaling wave *s*. It is therefore contemplated that any method of operation or means for performing such method whereby the grid voltage of an amplifier for amplifying a zero carrier wave is caused to pass through variations at double the modulation frequency of the modulating wave is an embodiment of the present invention. It also appears that the principles of the invention are applicable in amplifying any modulated wave of which the amplitude at times approaches zero, i. e. complete modulation.

Among the possible arrangements functioning in accordance with the diagram of Fig. 4, is the circuit arrangement indicated in Fig. 1, which will now be described.

In Fig. 1, the tube 1 and its associated circuit arrangements comprise an oscillation generator which may generate any desired frequency of carrier wave. By way of illustration, it may be assumed that the frequency produced by the oscillation generator 1 is 100,000 cycles per second. The microphone circuit 2 typifies any desired source of modulating waves, oscillations, or impulses in accordance with which the oscillations produced by the generator 1 are to be modulated. The vacuum tubes 3' and their associated circuit arrangements constitute a modulator 3 of the well-known carrier suppression type. The function of the modulator is to modulate the waves from the generator 1 in accordance with waves from the source 2 and largely suppress the unmodulated carrier component. The operation of the modulating system 3 is fully described in U. S. patent to Carson No. 1,343,306 granted June 15, 1920.

Before being applied to the power amplifying system 4, indicated as consisting of a number of vacuum tubes 5 connected in parallel, the zero carrier waves produced by the modulating system may be separated from any interfering waves by means of a selective circuit arrangement 6, and increased in energy in one or more stages of amplification by means of vacuum tube amplifiers 7 and 8. The amplifiers 7 and 8 are of a conventional type well known in the art and need not detailed description. The selective circuit 6 preferably consists of a band pass filter of the type described in U. S. patent to Campbell No. 1,227,113, granted May 22, 1917. The filter 6 may pass a range of frequencies consisting of the lower side band, that is, for example, from 98,000 to 99,800 cycles per second; or the upper side band, that is, from 100,200 to 102,000 cycles per second; or it may pass both side bands, that is, from 98,000 to 102,000 cycles per second.

In the present instance, we will assume that both side bands are transmitted by the filter 6 and that the unmodulated carrier component is wholly suppressed by the modulator 3 inasmuch as the wave form thereby resulting is that indicated by the curve *s* in Figs. 3 and 4. The curve *s* in Fig. 4 represents the same modulated wave as the curve *s* in Fig. 3 but in the case of Fig. 4 the zero axis of the wave *s* is curved instead of being straight as in Fig. 3.

It is in the power amplifying system 4 that large amounts of power are dissipated, this power being supplied from the space current source 9. The power consumption in the amplifiers 7 and 8 is too small to necessitate the application of the invention to their input circuits. In accordance with the present invention, the battery 10 should be adjusted to or at about the point where space current flows in the amplifier tubes 5. A rectifier 11, preferably in the form of an evacuated tube having a cathode and an anode, is connected across between the grids and the filaments of the tubes 5 so that incoming waves will be partially rectified in a manner tending to make the grid more negative. The greater the amplitude of the waves, the more negative the grids will become. Hence, when waves of large amplitude are being amplified, the efficiency is correspondingly high and when waves of small amplitude are being amplified the tubes work only on the lower part of their characteristic and but little energy is dissipated. See paper "Modulation in radio telephony", Proc. I. R. E. August 1921, Appendix. It is preferred to include the battery 10 in series with a high resistance 12, and to shunt the rectifier 11 around the resistance 12. Another resistance 13 is preferably included in circuit with the rectifier to determine the potential applied to the rectifier. The resistances 12 and 13 should be varied both with respect to each other and the other constants of the system until a desired operating condition is obtained.

The operation of the system is indicated in Fig. 4 and has been described above. The grid potential of the tubes 5 is set at the value at which space current just begins to flow. Incoming high frequency waves then have some of their current rectified in the rectifier 11 and cause the grid potential of the tubes 5 to fall to a still more negative value. During those parts of the modulating wave cycle when the high frequency waves are of small amplitude the negative charge on the grid caused by the rectified current will leak off through the resistance 12. The curve MN (Fig. 4) represents the variation of grid potential. The negative potential of the grid thus rises and falls in such a manner that when large waves are amplified, the grid is at such a high negative potential as to create an efficient operating condition. When small waves are amplified, only a small amount of power is needed, hence the average efficiency over a complete low frequency cycle remains fairly high. Whatever distortion is introduced does not result in loss of essential elements of the voice wave. The high power waves in the output circuit are transferred to the antenna circuit 14 by means of the coupling between the coils 15 and 16.

The grid of the power amplifier tubes is automatically caused to vary in potential at a frequency twice the frequency of the modulating wave. This mode of operation comprises one of the important features of the present invention. It may be accomplished in different ways with varying forms of apparatus. The arrangement herein illustrated is one of the arrangements, but by no means the only arrangement which may be devised for carrying out this method.

Thus, in the circuit of Fig. 5, a portion of the modulating wave energy is utilized to control the grid potential of the power amplifier. Modulating waves are applied from the microphone circuit 2 to the modulator 3 which is supplied from source 1 with a carrier wave to be modulated. The resultant zero carrier modulated waves are applied to the input circuit of a power amplifier system 4. Some of the speech frequency energy from the circuit 2 is amplified by the amplifier 17 and applied to a double rectifier system 18 consisting of two hot filament evacuated tubes 19 and 20. The tubes 19 and 20 rectify the alternate half waves of the alternating current of speech frequency supplied by the amplifier 17 and thus cause the grids of the power tubes of the system 4 to vary in potential in accordance with the curve MN of Fig. 4. The resistance 21 serves as an impedance element across which the electromotive force resulting from the rectified current is applied to the grid circuit of the tubes 4.

The novel features which are believed to be inherent in the invention are defined in the appended claims.

What is claimed is:

1. The method of repeating at high efficiency, as regards power consumption, a modulated wave by means of a space discharge repeater having a control element, which comprises supplying to the control element a negative voltage of such a value as to just allow the repetition of waves of small amplitude and automatically increasing this negative voltage in a ratio proportional to the magnitude of the waves when waves of large amplitude are to be repeated.

2. The method of repeating a zero carrier modulated wave comprising a carrier wave modulated in accordance with a lower frequency wave,—the unmodulated component

being largely suppressed,—by means of a space discharge device having a grid or control element which comprises varying the polarizing potential of the grid periodically at a frequency twice the frequency of the lower frequency wave.

3. The method of repeating a wave of a given frequency having amplitude variations in accordance with a modulating wave of a given frequency by means of a space discharge device having a grid or control element which comprises varying the potential of the grid periodically at a frequency twice the frequency of the modulating wave.

4. The method of repeating a high frequency wave of variable amplitude by means of a space discharge device which comprises rectifying a portion of the high frequency wave energy by means of a device other than the space discharge device and applying to the space discharge device a potential difference resulting from the rectification to control the repetition of the high frequency waves by the space discharge device.

5. The method of high frequency wave amplification by a discharge device amplifier containing a control element which comprises applying a portion of the high frequency energy which is to be repeated to a rectifier and applying to the control element of the amplifier a resultant negative voltage which varies periodically at a frequency twice that of the high frequency wave.

6. A vacuum tube repeater having input electrodes, a rectifier connected between said electrodes, a resistance in series with said rectifier, and a high resistance connected between said electrodes in parallel to said rectifier which supplies rectified current thereto for applying a varying potential between said electrodes.

7. In combination a vacuum tube repeater for repeating only impulses of a zero carrier wave of one polarity, a rectfiier in shunt thereto for varying the grid potential of said repeater at a frequency double the frequency of the modulating wave, and a resistance in series with said rectifier.

8. The method of amplifying a wave having components of fixed and variable frequencies by means of a space discharge device having an anode cathode and control electrode or grid which comprises varying the grid polarizing potential as a function of the amplitude of one of the wave components.

9. A vacuum tube repeater having grid, filament and plate electrodes, an input circuit including said grid and filament electrodes, means for impressing waves to be repeated on said grid and filament, a high resistance in series with a source of electromotive force connected across said input circuit, and, in shunt to said resistance, a rectifier controlled by said waves whereby a varying biasing potential is applied to said grid.

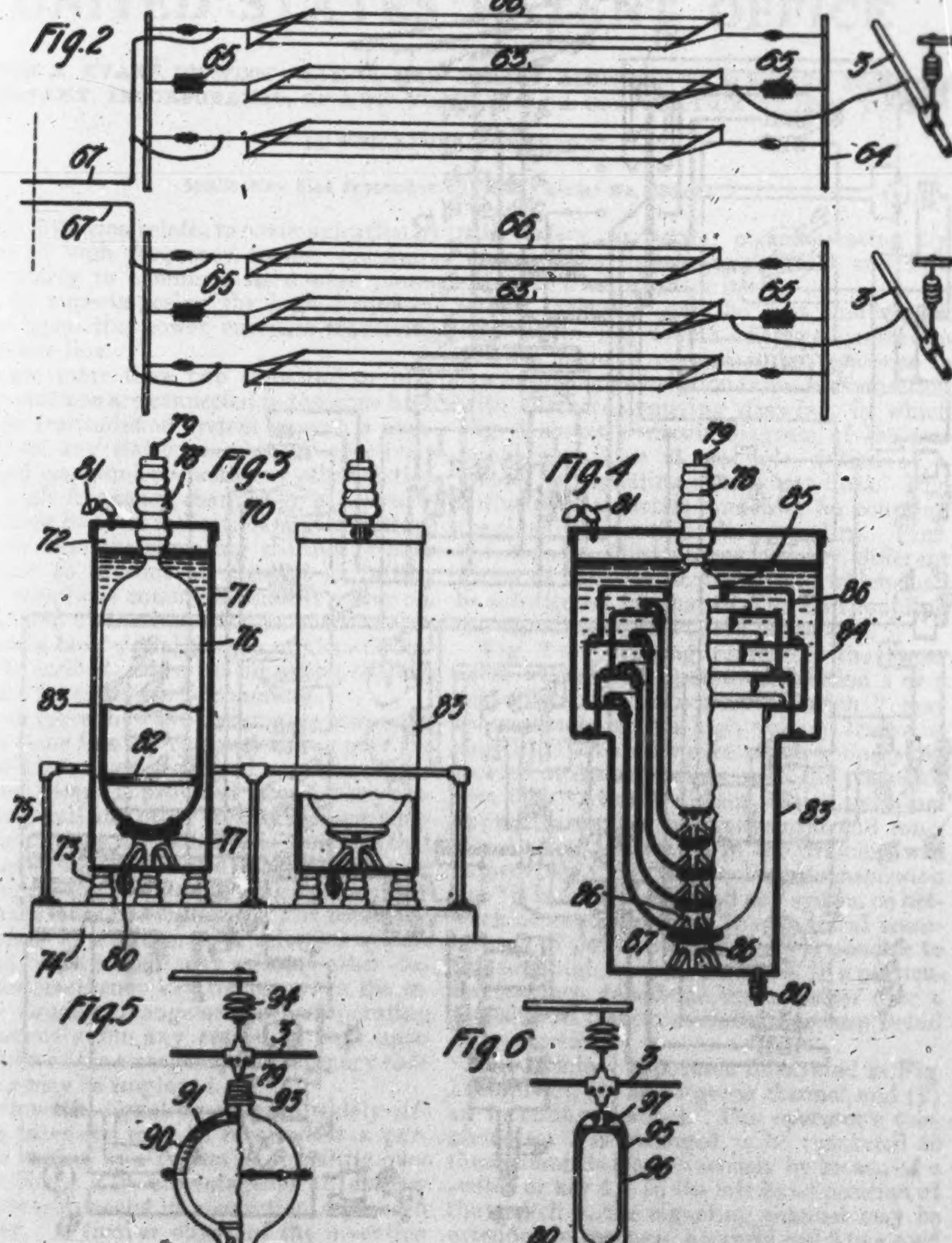
In witness whereof, I hereunto subscribe my name this 28th day of December, A. D. 1922.

RAYMOND A. HEISING.

Nov. 26, 1929. P. H. EVANS 1,736,852

POWER LINE SIGNALING

Filed Sept. 24, 1923 2 Sheets-Sheet 2



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POWER LINE SIGNALING

Filed Sept. 24, 1923 2 Sheets-Sheet 1

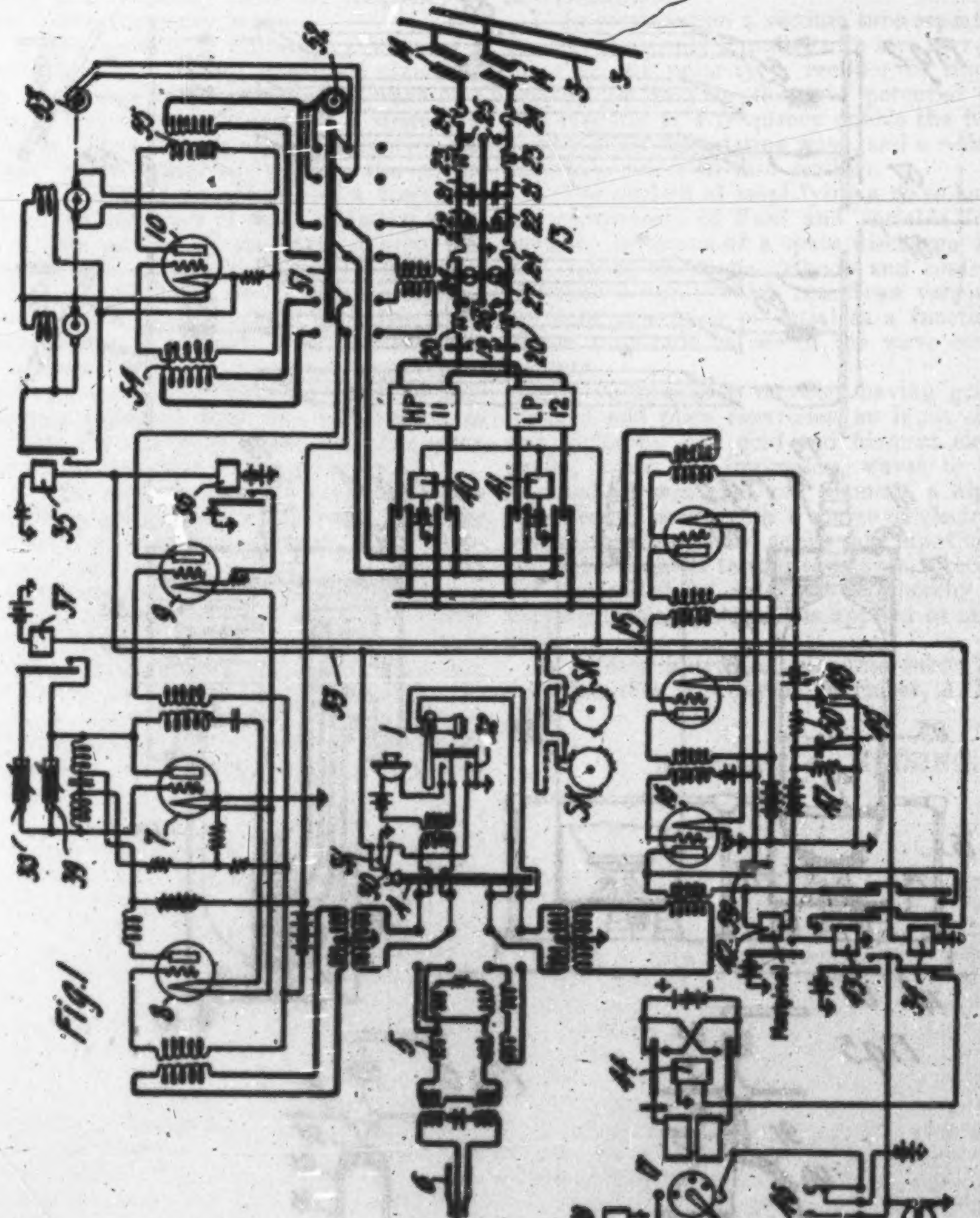

Fig. 1

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POWER-LINE SIGNALING

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This invention relates to communication by means of high frequency waves, and more particularly to communication over power lines by superimposing the high frequency waves upon the power currents traversing the power line.

Where more than two signaling or telephone stations are connected to the same high voltage transmission system in such a manner than any station is able to selectively call and communicate with any other station on a high frequency channel, it is desirable that there be some indication at idle stations to show that the signaling channel is busy in order to prevent an attempt at calling while telephone communication is going on. One object of the invention is, therefore, to provide a busy signal at each of the idle stations to indicate when the signaling channel is in use for calling or telephoning.

When more than two stations are connected on the same line for communicating over the same high frequency channel or channels and selective means is provided whereby any station may call any other station without ringing the stations not called, it is desirable that arrangements be provided for ordinary code ringing in the manner of ringing on party telephone lines be employed. The invention comprises in addition to a selective system whereby each station may call any other station, an emergency key for use when the selective ringing arrangement is not operating satisfactorily for any reason so that upon operation of the emergency key ordinary code ringing may be employed.

Inasmuch as signaling waves of widely differing intensity may be received at a particular station in a system of signaling over power lines, it is advantageous to employ gain control means in connection with each receiver. A further object of the invention is to provide automatic gain control whereby the amplification of incoming waves is decreased as a result of the reception of wave energy above the normal volume.

Another object is to provide for connecting signaling apparatus to a power line for transmission thereover by such coupling apparatus as will combine efficient signaling with safety to person communicating by means of the signaling apparatus and with safety to the apparatus itself.

The invention will be best understood, both as to the details of its organization and its mode of operation, by reference to the following description taken in connection with the accompanying drawing, in which Fig. 1 shows a circuit diagram of the terminal apparatus at a single station of a system for signaling over power lines. Fig. 2 illustrates an aerial condenser for coupling the signaling circuit to the power line. Figs. 3, 4, 5, and 6, illustrate respectively, different forms of capacity arrangements which may be substituted for that of Fig. 2 in coupling the signaling system to the power line.

Fig. 1 of drawing represents the apparatus whereby an operator at station 1 or a subscriber at a subscriber's station 2 may communicate over a high voltage transmission line 3 with other subscribers or operators located at distant points upon the transmission line. At each distant station, terminal apparatus similar in arrangement and function to that illustrated in the drawing will be provided. By "high voltage transmission line" it is to be understood any system or network of conductors for the electrical transmission of power over which it is possible to transmit high frequency waves. In a particular instance, telephone transmission over a 110,000 volt transmission line has been found to be practical.

The terminal apparatus illustrated in Fig. 1 comprises, (1) an outgoing channel, and (2) an incoming channel. The operator's telephone set 1 is arranged to be connected to these channels simultaneously by means of a switch or key 4. In the left-hand position of the switch 4, the signaling channel may be extended by means of a hybrid coil 5 to a cord and plug connection 6 at a telephone switchboard whereby the circuit may be further extended to any subscriber or telephone network.

The outgoing channel comprises (1) a high frequency wave generator 7 designed to produce waves at two different high frequencies, for example, 80,000 and 100,000 cycles per

second, which will hereinafter be referred to as frequencies f_1 and f_2 respectively; (2) an amplifying and modulating tube 8 and its associated circuits whereby the outgoing waves are modulated in accordance with speech; (3) an amplifier 9 and its associated circuits whereby the waves produced by the oscillator 7 may be amplified to sufficiently high power for transmission under normal conditions; (4) an auxiliary amplifier 10 and its associated circuit connections which may be connected into circuit to increase the power amplification for transmission under abnormal conditions, as for example, when a section of the line is down; (5) high pass and low pass filters 11 and 12 which may be included in the transmission circuit alternatively by means of apparatus hereinafter described; (6) a coupling circuit 13; and (7) coupling capacities 14, the coupling circuit and coupling capacities being common to the incoming and outgoing transmission channels and serving to couple the signaling apparatus with a selected pair of power line conductors.

The receiving channel extends from the power line through the coupling condensers 14, the coupling circuit 13, to the high pass or low pass filter 11 or 12, and includes, in addition to these elements, (1) high frequency amplifying apparatus 15 for amplifying in one or more stages the incoming waves and (2) a rectifying or detecting tube 16. For calling purposes, the incoming channel is normally extended by means of relays through the circuit of a selector 17, which controls a bell or other signaling device 18. The selector 17 is the type of device described and claimed in the patent to J. C. Field, No. 1,200,095, granted October 3, 1916, and No. 1,343,256, granted June 15, 1920.

For efficient signaling it is essential that the signaling circuit be connected with the power line in such a manner as to effect a suitable transfer of energy from the signaling circuit to the line and from the line to the signaling circuit. For protection of the signaling apparatus and persons communicating thereover, it is essential that direct contact with the high voltage lines be avoided. The coupling condensers 14 may comprise any suitable arrangement whereby a capacity of a sufficiently large value is provided between the terminals of the signaling circuit and the conductors of the power line. Such a capacity may be provided by a fixed condenser adapted to withstand the high voltages or an arrangement of aerial wires arranged adjacent to the power line conductors. It has been proposed to employ a section of high voltage cable, the core of which constitutes the power line conductor and the sheath of which serves as a plate of a condenser to which the signaling circuit is connected. However, the manufacture of cable adapted to continuously withstand the high voltages met with is a matter of considerable difficulty. The preferred coupling arrangement consists of a fixed condenser with either oil or porcelain dielectric or an antenna arrangement. The coupling circuit comprises condensers 19 and choke coils 20 in series with the line and condensers 21 and choke coils 22 in shunt to the line. The coils 22 serve also to shunt to ground any 60 cycle current entering the coupling circuit. Choke coils 23 are connected in the line adjacent the coupling condensers 14. Safety devices comprise fuses 24, open air spark gaps 25 and 26 of high current capacity and vacuum gaps 27 in shunt to the gaps 26. The vacuum gaps break down quickly under the influence of excessive voltages, and thus serve to protect the signaling circuit until the air gaps 26, which are adapted to carry a much heavier current than the vacuum gaps, come into operation.

Operation in calling.—The switch 4 is closed at its right-hand contacts, thus connecting the operator's set 1 to the high frequency circuit, closing the contact 30 and opening the contact 31. When the operator takes his receiver from the switchhook, the contact 32 is closed, thereby connecting ground to the conductor 33. The relays 34, 35 and 36 then operate. Since the selector keys SK, SK are normally closed, the operation of the relay 34 closes the contact on the inner armature and thus operates the relay 37. It will first be assumed that line conditions are normal and that the auxiliary amplifier 10 is not to be used, in which case the relay 35, although closed, performs no function. Under such conditions, the switch 51 is closed in the down position. The relay 36 closes the filament heating circuits of the modulating, generating and amplifying apparatus 8, 7, 9. The operator now actuates one of the keys SK corresponding to the station desired to be called and thus causes the relay 37 to operate each time a tooth of the selector key opens the circuit of the relay 37 thereby placing the condenser 38 into and out of circuit once for each impulse transmitted by the selector keys. Normally the high class filter 11 is connected to the transmitting channel and the low pass filter 12 is connected to the receiving channel. However, when the relay 34 was operated as aforesaid, the relays 40 and 41 became operated and thus interchanged the high pass and low pass filters so that the low pass filter 12 is connected to the transmitting circuit and the high pass filter 11 is connected to the receiving circuit. During the operation of the selector key, the frequency generated by the oscillator 7 is thus changed back and forth from the low carrier frequency f_1 to the high carrier frequency f_2 and vice versa. However, the high carrier frequency is not transmitted to the line inasmuch as the low pass filter is designed to pass

only the low carrier frequency and to suppress the high carrier frequency. The groups of impulses of the low carrier frequency are thus transmitted to and impressed upon the power line. When the selected station answers, the operator at the calling station may converse by means of his telephone set and if desired he may extend the connection through the hybrid coil 5 and the plug 6 to a telephone switchboard or any subscriber whose line is permanently attached to the plug connection 6. When throwing the switch 4 from the right-hand position to the left-hand position it is essential that the contact 31 be made before the contact 30 is broken in order to hold the ground connection upon the conductor 33 and thus maintain the circuit.

When the oscillator 7 at the called station transmits high frequency impulses to the line, relays 42 and 43 at the calling station will not be operated and the relay 44 will not be actuated because the relay 34 remains operated at the calling station thus maintaining the circuit of the relay 44 open at the left-hand contact of the relay 34.

The station originating a call always transmits on the lower of the two carrier frequencies and receives on the higher.

Operation at a called station.—The electrode circuits of the amplifier 15 and the rectifier-detector 16 are normally energized. Incoming high frequency impulses are rectified by the rectifier 16. This increases the space current of the rectifier 16 and operates the differential relay 42 inasmuch as the outer armature contact of the relay 34 is opened. The operation of the relay 42 causes the operation of the relay 43 thus closing its left-hand contact and connecting the battery through the relay 44 which causes it to operate and supply an impulse of current to the electromagnet of the selector 17 which causes the selector to operate one step. When the incoming oscillations cease, the relays 42, 43 and 44 release which causes an impulse of current of opposite sign through the magnet of the selector 17. A proper series of impulses will cause the selector to close the circuit of the bell 18. At the cessation of the calling impulses the frequency f_1 is continuously transmitted to the line at the calling station and the relays 42 and 43 are maintained operated at the called station. Therefore, when the operator at the called station removes his receiver from the switchhook and places ground upon the conductor 33, thus operating the relay 34, the relays 40, 41 and 37 do not operate because the path to ground through the inner contact of the relay 43 is broken. Consequently, the high pass filter 11 at the called station remains connected to the transmitting channel and the low pass filter 12 remains connected to the receiving channel. The generator 7 oscillates at the higher carrier frequency f_2 and sends to the line a continuous train of oscillations through the high pass filter 11. The operators or subscribers may now converse with each other inasmuch as at each station the outgoing oscillations will be modulated in accordance with speech and the incoming oscillations will be detected by the detector 16 and impressed upon the telephone circuit. The called station always transmits on the higher of the two carrier frequencies and receives on the lower.

Operation at an idle station.—When oscillations of the frequency f_1 are impressed upon the line, the relays 42, 43 and 44 are actuated once for each group of impulses. However, if the spacing of the impulses is not that for which the selector 17 is set, the selector 17 does not close the circuit of the bell 18, but, at the cessation of the incoming impulses, the selector returns to its normal position. Each impulse of current of the frequency f_1 will actuate the relays 42 and 43 as stated before and the left-hand contact of the relay 43 closes a circuit through the lamp 45. When the called station answers and high frequency current is continuously upon the line, the relay 43 is maintained energized and the lamp 45 remains lighted thus indicating that the circuit is busy. Operators at idle stations are thus warned not to attempt to call upon the circuit whereby they are able to avoid interfering with conversations in progress.

Emergency key operation.—If line conditions are too abnormal to allow code selective ringing, if the selector circuits are not operating properly, if there are only two stations upon the line, or, if it is desired to arrange so that all the stations may be called simultaneously from a chief operator's or dispatcher's station, the key 46 may be operated. High frequency impulses put upon the line will then cause the relay 43 to close a circuit directly through the bell 18. If continuous oscillations are put upon the line, the bell 18 at each station where key 46 is operated will ring continuously or any predetermined code of ringing may be employed. The selector keys SK in this case are employed to transmit impulses or a hand key may be used in place of the selector keys in a manner which will be obvious. It is customary in connection with the use of selectors such as the selector 17 to provide one selector key SK at a chief dispatcher's office with an arrangement of teeth adapted to call all the stations upon the line simultaneously. This mode of operation may be employed in the present instance, if, for example, an emergency renders it necessary for the dispatcher to give directions to attendants at all the stations simultaneously.

Automatic gain control operation.—In the anode-cathode circuit of the detector tube 16, is connected a resistance 47. The space current of the tube 16 flows through this resist-

ance. The grids of the tubes of the amplifier 15 are normally polarized by a source 48. When normal strength waves are coming in, the additional polarizing potential due to the drop across the resistance 47 just suffices for normal amplification. When waves of unusual strength are incoming the drop of potential across the resistance 47 is increased thus increasing the negative polarization of the grids of the tubes of the amplifier 15 and automatically reducing the amplification of the received waves. The grid of tube 16 may also be connected to the same terminal of the battery 48 to which the grids of the amplifier tubes 15 are connected. Also the grid of tube 16 may alone be thus connected and the grids of tubes 15 may be connected to ground through an invariable biasing battery. Condensers 49 and resistance 50 serve as a grid circuit filter and serve the double purpose of shunting speech frequency variations around the resistance 47 and preventing the amplifier 15 and detector circuit 16 from acting as an oscillation generator because any oscillations generated in the plate circuit of the tube 16 which tend to be fed back to the grid circuits of the amplifier are largely shunted through the combination of resistance 50 and capacities 49. A condenser 59 bypasses carrier frequency waves around the relay 42.

Auxiliary amplifier circuit operation.—If line conditions are bad owing to a break in the line or a section of the line being down, the switch 51 is moved from the normal down position to the up position, thus connecting a power source 52 to the motor generator 53 and energizing the plate and filament circuits of the power amplifier 10. The outgoing channel will then extend from the plate circuit of the amplifier 9 through the high frequency transformer 54 to the grid circuit of the amplifier 10 and from the plate circuit of the amplifier 10 through the high frequency transformer 55 and the high or low pass filter 11 or 12, as the case may be, to the line. The tube 10 is a tube amplifier of considerable output, capable of supplying from five to twenty times more energy than the power normally used for transmitting.

It is contemplated that the coupling circuit 13 should have the transmission characteristic of a very flatly tuned circuit or preferably that it should have the characteristic of a band pass filter, thus transmitting with negligible attentuation currents of frequencies of 80,000 and 100,000 cycles per second or whatever frequencies are used in the particular system. Such a band filter characteristic may be obtained by properly choosing the capacities 19 and 21, inductances 20, 22 and 23, and the capacities 14. If the signaling circuit side of the capacities 14 has a capacity to ground this must also be taken into account in designing.

Fig. 2 shows apparatus for connecting the signaling circuit to the power line conductors 3. This apparatus corresponds to and may be used in lieu of the capacities 14 in the circuit of Fig. 1. The aerials 63 are mounted upon suitable supports 64 and connected with the two conductors of the power line 3 which are to be used for transmission. When the power line 3 consists of several multiphase conductors any two conductors may be selected as signaling conductors. The aerials 63 are at the potential of the power line conductors to which they are connected and are insulated by suitable high voltage insulators 65. Adjacent to each antenna 63 is an aerial 66 which may comprise a plurality of sections, preferably two, as illustrated in Fig. 2, located one upon each side on the antenna 63 and equidistant therefrom. Each pair of aerials 66 is connected by suitable leads 67 to the signaling apparatus through the coupling circuit 13. The antenna or aerial condenser described may be located either in a horizontal or a vertical plane. That is, the antennae 66 may be respectively above and below the antenna 63 or may be positioned at the sides thereof. This coupling arrangement has numerous advantages. A sufficiently large capacity to connect the power line and the signaling apparatus is readily attained. The supports 64 and the aerials 63 and 66 may be constructed in a manner to withstand extreme weather conditions and thus avoid danger of direct conductive contact between the signaling circuit and the power line even if that portion of the power line immediately adjacent the antenna structure should break and fall to the ground. The respective conductors 3 of the transmission circuit act in series to form a path in shunt across the power line terminals of the coupling circuit 13. It is accordingly very difficult to predetermine the characteristics of this termination since the capacities from the conductors 3 to ground are determined primarily by the power lines and are not readily subject to control or variation to meet the requirements of the signaling circuit. In the case of the separate capacity coupling structure illustrated in Fig. 2, however, it is possible to predetermine the capacity between the aerial 63 and ground and to design the coupling circuit 13 accordingly.

Fig. 3 illustrates a battery of two coupling condensers 70 of another type, each of which comprises a metal tank 71 filled with oil to a suitable level, as at 72, and mounted on high tension insulators 73 on a base 74 of concrete or like material. These condensers operate at extremely high voltages and, although the tank 71 is at relatively low voltage with respect to ground, it is desirable in the interests of safety to surround the battery of condensers with a guard rail or equivalent device 75. The condenser comprises, in addition to the container 71 which serves as a low potential plate, a hollow interior member 76, fixedly

supported within the container 71 by means of the lower supporting member 77 which may be in the form of a tripod formed of insulating material and secured to the member 76, and the high tension insulating bushing 78 through which connecting lead 79 may be taken to the high tension line. In order to permit drainage of this condenser to remove water or accumulated sediment, a drainage pipe 80 provided with a valve is connected to the lower portion of the tank. To permit of necessary expansion and contraction within the tank, a vent member 81 which is so designed as not to admit rain or snow is connected through the upper portion of a cap member of the tank. The interior plate 76 is preferably formed of a cylinder to which are soldered or welded hemispherical ends. In order to avoid any "fringing" or brush discharge, the interior surface of the tank 71 and the exterior surface of the interior plate 76 are made as smooth as possible. The interior plate 76 may, for example, be joined to the hemispherical portion by a butt joint, in order to avoid sharp edges and rough surfaces. In such cases an overlapping ring 82 within the member 76 may be used to reinforce the joint. This construction enables the high tension electrostatic condenser to be built with the requisite capacity and without employment of a very large quantity of oil or other dielectric. It will be understood that the two condensers of the battery 17 may be employed to replace the two condensers illustrated in Fig. 2, the connections 79 from the respective condensers leading to the high power transmission conductors 3, and the low tension terminals 83 leading to the signal coupling circuit 13.

Fig. 4 illustrates a modified form of oil dielectric condenser provided with a plurality of plates. As in the apparatus of Fig. 3, the low tension plate of the condenser comprises an oil-filled container 84. The high tension plate 85, connected to the power line by lead 79 extending through the high tension insulating bushing 78, is similar to the high tension plate 76 of the condenser of Fig. 3. Placed within the tank 84 and surrounding the plate 85 are a number of centrally aligned tubular plates suitably spaced from each other and supported at their lower ends by a series of insulating supports 86. These plates are alternately connected to the tank 84 and the high tension plate 85 and thus serve with the plates 84 and 85 to constitute a multi-plate condenser. The connecting members 86 which serve to electrically connect the high tension plates to each other and the low tension plates to each other are, in effect, also supporting brackets, and support the high tension plates from the inner plate 85 and the low tension plates from a ledge on the inner wall of the low tension plate or tank 84. In order to permit circulation of the oil around and through the tubular plates and to permit accumulations of water and sediment to be withdrawn, each of the tubular plates is provided with a drainage aperture 87 through which the heavier material may pass toward the bottom of the tank 84. In this apparatus, as in that of Fig. 3, the oil level is preferably kept to a point above the exposed surface of the interior high tension plate. Moreover, in both designs, the surfaces from which "fringing" is apt to occur are curved and so shaped as to avoid sharp angles and points.

In Fig. 5, there is disclosed an arrangement consisting of an exterior sphere 90 and an interior sphere 91. The space between the two spheres is filled with oil or other suitable dielectric. The outer member 90 is preferably formed of two hemispheres, bolted, or otherwise suitably secured together in such manner as to present a smooth interior surface. The outer shell is also provided with the usual drain pipe 80 and a low tension connecting lead 92. The entire structure is supported from a high tension insulating bushing 93 which extends through the upper portion of the outer sphere 90 and serves not only to effectively insulate the connecting lead 79 but also as a mechanical support for the interior sphere as well. This insulator is supported directly from the power conductor 3, preferably at a point just beneath and in line with a suspension insulator 94 which serves to support the power conductors 3 thus transferring the mechanical strain directly to the transmission line tower. This structure has the advantage that for a given electrostatic capacity, a minimum quantity of oil or dielectric is required.

In the modification of Fig. 6, the condenser consists of two tubular members 95 and 96, the outer of which serves as the high tension plate and is directly connected to the high tension transmission conductor 3. The interior plate 96 is held in position within the exterior plate by means of a spacing insulating support 97 and the high tension insulator 98. The low tension conductor 99 is, in this instance, insulated from the high tension plate by means of the insulator 98 and is electrically connected directly to the low tension plate 96. Inasmuch as the high tension plate 95 substantially completely shields the low tension plate 96, the resulting capacity to ground from this structure is very small.

Certain features of the system herein described are disclosed and claimed in the copending application of W. V. Wolfe, Serial No. 664,147 filed simultaneously herewith.

Obviously many of the features of this invention are applicable to signaling systems generally and it is therefore to be understood that the invention is not to be limited to the systems disclosed.

What is claimed is:

1. In a system for signaling, a high voltage transmission line, a plurality of stations connected to said line and each having high frequency transmission and high frequency reception apparatus, means at at least one station to selectively call any other station and communicate therewith telephonically with waves of a predetermined frequency, and means at an idle station actuated by calling or telephone currents to indicate that the signaling circuit is busy.

2. In a system for communicating by carrier waves, a high voltage transmission line, a plurality of stations connected to said line, means whereby each station is normally conditioned for the reception of a call on a wave of one frequency, means whereby any station calling transmits waves over said transmission line of that frequency for calling and telephoning, and means at an idle station whereby waves of that frequency indicate that the signaling system is busy.

3. In a carrier wave communication system, means comprising a transmitting key for sending groups of waves of a predetermined frequency to the medium connecting the stations in predetermined number and order, a selective device at a station to be selected responsive only to the currents corresponding to predetermined number and order of impulses for operatively affecting the circuit of an indicating device, and a circuit varying device which upon being operated, connects the indicating device in circuit to be operated directly as a result of the operation of the transmitting key without the actuation of a selective device.

4. Apparatus for connecting a signaling circuit to power line conductors for full metallic circuit communication over the power line conductors comprising an aerial connected to each of the conductors, means for supporting said aerials at a point away from the power line, said aerials being supported independently of the power line conductors, and other aerials supported adjacent to the first-named aerials respectively and connected to the terminals of the signaling circuit to effect a capacity connection between the signaling circuit and the power line.

5. A capacity device for connecting a power line and signaling apparatus comprising an elevated structure located at a point away from the power line, parallel aerials supported thereby independently of the power line, one of said aerials being electrically connected to said power line, and another of said aerials being electrically connected to said signaling apparatus.

6. In a system for communication over a power line, a high voltage transmission line, a plurality of stations connected to said line, means at each station for selectively calling any other station by a predetermined number and order of impulses of current of a predetermined frequency, means at the calling station for effecting telephone communication with the called station using said wave of predetermined frequency as a carrier, and means at each idle station controlled by calling or telephone current from the calling station to indicate that the circuit is busy.

7. In a carrier wave communication system, a plurality of stations, a transmitting medium connecting said stations, a transmitting key at at least one station for sending groups of waves of a predetermined high frequency in predetermined number and order to the medium connecting the stations, a selective device at each station responsive only to a predetermined number and order of impulses for operatively affecting the circuit of an indicating device, means at the calling station for effecting telephone communication with the called station using said predetermined frequency as a carrier wave, and means at each idle station controlled by calling or telephone current from the calling station to indicate that the circuit is busy.

In witness whereof, I hereunto subscribe my name this 23 day of September A. D., 1923.

PORTER H. EVANS.

Dec. 3, 1929. E. I. GREEN 1,738,000

MEANS FOR AND METHOD OF VOLUME CONTROL OF TRANSMISSION

Filed Aug. 5, 1926

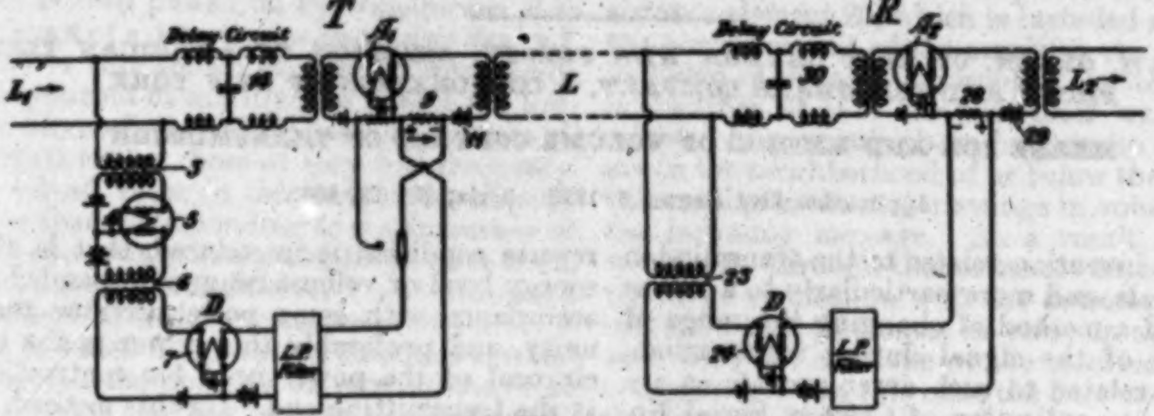

Fig. 1

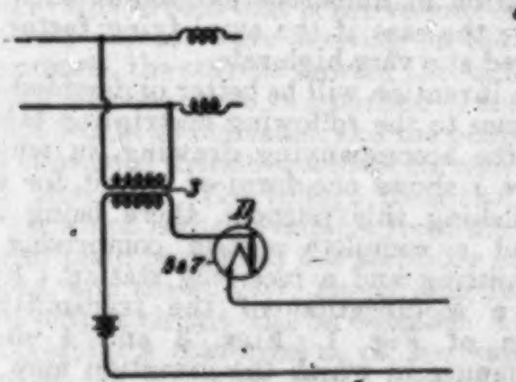

Fig. 2

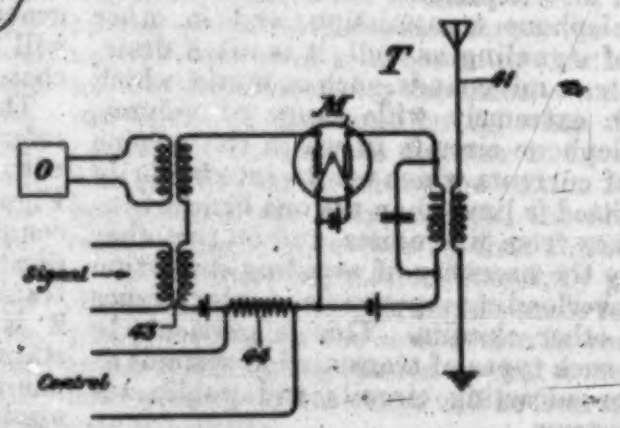

Fig. 3

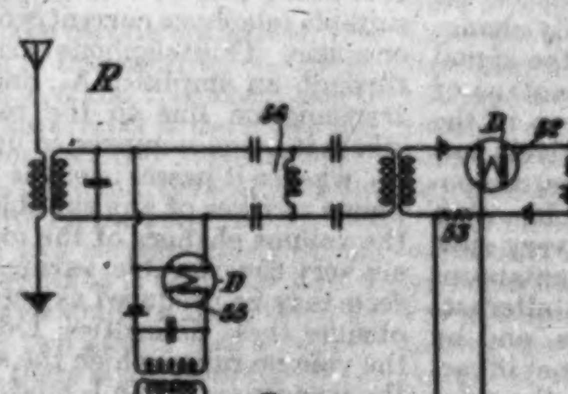

Fig. 4

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BY
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ATTORNEY

Patented Dec. 3, 1929 1,738,000

UNITED STATES PATENT OFFICE

ESTILL I. GREEN, OF EAST ORANGE, NEW JERSEY, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK

MEANS FOR AND METHOD OF VOLUME CONTROL OF TRANSMISSION

Application filed August 5, 1926. Serial No. 127,394.

This invention relates to the transmission of signals, and more particularly to a means for and a method of changing the range of volume of the signal during transmission, and is related to such arrangements as are shown in application of Crisson, Serial No. 737,415, filed September 12, 1924.

In telephone transmission, and in other kinds of signaling as well, it is often desirable to transmit sounds, such as music, which have an extremely wide range of volume, over telephone circuits in which the volume range of currents which can be satisfactorily transmitted is limited on the one hand by interference from line noises, and on the other hand by the necessity of avoiding distortion due to overloading repeaters and interference on the other circuits. This is particularly true of such types of transmission systems as radio broadcasting circuits and public address systems.

In this invention, it is proposed to bring the signal within the volume limits of the transmission system by automatically changing the shape of the envelope of the signal wave, and I do this by taking advantage of the fact that the changes of volume in the voice or other signals occur at relatively low frequencies in comparison with the component frequencies of the signal. In other words, the changes of volume are very slow compared with the almost instantaneous changes of magnitude involved in alternating frequencies in the voice range, and by controlling the transmitted volume in accordance with the major swings in the voice current, the desired end may be attained.

More specifically, this is accomplished by applying the wave to a repeating or amplifying device, such as a thermionic amplifier, and modifying the amplifying factor in accordance with these relatively slow major changes in the energy level of the wave. The modification at the transmitting end obviously will be in such a direction as to reduce the energy level range, and in this invention I propose to make the amplifying or repeating factor proportional to some root or power less than unity of the envelope of the current wave. At the receiving end, the reverse condition is introduced, that is, the energy level or volume range is expanded in accordance with some power greater than unity, and preferably this power is the reciprocal of the power used for contraction at the transmitting end. By this method, it is possible to avoid very substantially the generation of numerous harmonics, such as will be the case if the amplifying factor is changed at a very high rate.

The invention will be better understood by reference to the following description taken with the accompanying drawing, in which Figure 1 shows one form of circuit for accomplishing this purpose, there being indicated a complete system comprising a transmitting and a receiving station. Fig. 2 is a modification of the transmitting station of Fig. 1. Figs. 3 and 4 show one manner in which the invention may be applied directly to radio communication.

Referring more specifically to Fig. 1, there is shown a line L_1 over which will come any suitable telephone current generated by speech or music. This telephone current wave passes through an amplifier A_1, and thence over a transmission line to the receiving station where it is again impressed upon an amplifier A_2, whence it passes over the line L_2 to a telephone receiver of any suitable form. In case the volume changes of the incoming message are very considerable, various undesirable effects may be produced as noted above, and to obviate these difficulties, I desire to narrow the volume range which the amplifier A_1 and the transmission line L must carry. Accordingly, across the line L_1 there is connected a transformer 3, the secondary of which is connected to the input circuit of a vacuum tube device 5, which device has a non-linear characteristic of such a form that the output is not proportional to the input, but is proportional to some root of that input, or, expressed in other words, is proportional to some power or exponent of that input, this power or exponent being less than unity. A very suitable value for this exponent to take, and one which it is convenient to use in visualizing this invention, is the exponent or power 5/10, in which case if an arbitrarily chosen portion of

the incoming wave is spoken of as having an energy amplitude of 1, and if another portion has an energy amplitude four times as great, then in the output of the device 5 the second portion of the wave will have an amplitude only two times as great as that of the first portion of the wave. This modified wave train is then passed on by transformer 6 to the input of a detecting or rectifying device 7, which is here shown as a thermionic device. In the output of this detector 7 there is a low-pass filter which will by-pass or suppress all currents except those of very low frequency, the cut-off value in this case being slightly above that corresponding to the frequency of the major swings in the telephonic wave train. The output of this detector 7 also includes a resistance 9, which resistance is at the same time included in the output circuit of the amplifier A_1, the polarity of connections from the detector 7 to the resistance 9 being as indicated on the drawing. Under these conditions, it will be seen that if the volume of the telephone current wave arriving on the line L_1 increases, the current flowing through the resistance 9 considered as a portion of the detector 7 would be increased, and the potential drop consumed therein would be correspondingly increased. The voltage from the battery 11, which is then available from the filament to plate portion of the amplifier A_1, is reduced, and the effective amplifying factor of the output circuit will be reduced. Thus, there results a compression of the volume range of the incoming signal message, the compression being in accordance with and controlled by the major swings in volume of that incoming message.

It is apparent that a certain amount of time has been consumed in transmitting the signal through the path 3, 5, 6 and 7, so that there is a certain delay in the arrival at the resistance 9 of the detected or rectified low frequency currents. On the other hand, the signal in being transmitted through the amplifier A_1, has not been subjected to a corresponding delay, and for the best results it is desirable that a corresponding delay should be introduced in order to bring the two effects into synchronism. To this end, there is shown in the input circuit of the amplifier A_1 a delay circuit 14, which may comprise inductances and capacities connected in a suitable manner to increase the time of transmission of signal, and thus introduce the necessary delay.

The signal, with the modified or contracted wave form, may now be transmitted over the line L to the receiving station R, at which it will ordinarily be desirable to reverse the process that is used for the previous contraction by applying a corresponding expansion. At this receiving station, there is shown an amplifier A_2 of the thermionic type, which in itself would naturally be chosen to have an approximately straight-line characteristic. In this case, also, however, the characteristic of the circuit as a whole may be modified by a side circuit consisting of a transformer 23 bridged across the incoming line L. The secondary of this transformer is connected to the input of a detecting or rectifying device 24, the output circuit of which includes a resistance element 28, which is included also in the output circuit of the amplifier A_2. Also included in the output circuit of the detector or rectifier 24 is a low-pass filter which is adapted to pass only those frequencies which are in the neighborhood of or below that corresponding to the major swings in volume of the incoming message. As a result, there would flow through the resistance 28, by virtue of its connection with the detector 24, a current which fluctuates in value in accordance with the envelope of the received contracted wave. In this case, the current from the detector D flows in such a direction that when variations occur in that current, the resulting potential difference across the resistance 28 will be in a direction to aid the battery 29, thus increasing the effective amplifying factor of the amplifier A_2 when the incoming current on the detector 24 increases. The amplifying circuit at the station R thus has a non-linear characteristic, the non-linearity being the reverse of that introduced at the transmitting station T, and, by proper choice of characteristics, may be made to completely neutralize the contraction introduced at the transmitting station so that a message with normal volume range will be transmitted over the line L_2.

Here, again, it will be desirable to introduce a delay in the arrival of the message at the input of the amplifier A_2 because of the time element involved in transmitting the message over the path 23, 24 and to the resistance element 28. Such a delay circuit is therefore shown at 30, this again being of any well-known form.

It is obvious that many variations may be introduced in this circuit arrangement without departing from the spirit of the invention. For example, the control may be obtained by placing the resistance element 9 in the input circuit of the amplifier A_1, as indicated in dotted lines, care, of course, being taken to have the connections properly poled. A similar change might be introduced at the receiver station. It is also apparent that instead of sending the message out on a line L, any suitable transmission channel might be used, such as a radio channel, in which case the amplifier A_1 could be connected to a suitable oscillation generator and modulation system connected to an antenna, this communicating with a corresponding receiving station. Also, it should be noted that the modifying characteristic of the tube 5 may be combined with the detecting or rectifying action of the tube 7, so that both functions are

performed by a single tube. Such a modification of that portion of the circuit is shown in Fig. 2, in which the transformer 3 is shown connected directly to a detector tube marked 5 and 7, this tube having the proper characteristic to perform both functions.

In some instances it may be found that the required compression of the volume range is so great that it cannot be conveniently accomplished through the control of a single amplifier as illustrated at A_1. Such cases may evidently be taken care of by the use of one or more additional compressors identical with or similar to the one shown at the transmitting side of Fig. 1, the several compressors being connected in series to perform the function desired. Correspondingly, additional receiving circuits connected in series may be used for the restoration of the original volume range.

In case this invention is to be used for carrier or radio circuits, or for radio broadcasting purposes, it may be desirable to control the extent of modulation of the carrier frequency, this control being exercised by the low frequency current arriving from the detector D. Similarly, at the radio receiving station it may be desirable to control the demodulating or detecting device in a corresponding manner. One method of accomplishing this is shown in Figs. 3 and 4, the first of which represents a radio transmitting station, and the second, a radio receiving station. In Fig. 3, there is shown the antenna 41, to which is connected a modulating tube M, this modulator being supplied with high frequency oscillations from the generator O, and with signal currents of normal wave form transmitted by the transformer 43. A suitable filter or tuned circuit may be inserted between the modulator M and the antenna 41 in order to eliminate the undesired products of modulation. In order to modify the extent of modulation in accordance with the volume arriving on the transformer 43, the efficiency of modulation would be controlled by the circuit 44 coming directly from the detector 7 and in effect serving as a variable, but slowly variable, bias on the modulating tube M. Similarly, at the receiving station R of Fig. 4, the demodulating or detecting efficiency of the detector 52 would be controlled by a corresponding slowly varying bias introduced in any suitable way, such as over the resistance 53, this slowly varying bias being derived from the detector 54, which in turn has received from the detector 55 the received signal frequency arriving on the receiving antenna. In this case, also, it might be desirable to introduce a delay circuit 56 in front of the detector 52 for the purposes already described.

Other methods of accomplishing the compression and expansion in carrier or radio circuits, such as, for example, the use of the control current to regulate the amount of the carrier current supply, will be readily apparent. Then again, in some cases it may be desirable to compress the volume range at the transmitting end without a corresponding expansion at the receiving end, and it is to be understood that all of these and other obvious modifications still come within my invention.

It should be pointed out that while in the description the element A_1 of Fig. 1 and the corresponding elements elsewhere are spoken of as amplifiers, the essential feature of the invention is that these elements shall be repeating elements adapted to compress the volume. While, in general, it will be convenient to have them increase the power, they may actually introduce a loss, corresponding to an amplification factor of less than unity and it is in this light that the term amplification factor should be interpreted in the specification and claims.

What is claimed is:

1. In a signaling system, a transmitting station, a source of a telephone current wave of varying volume, means for amplifying the wave, means associated with and adapted to modify the amplification factor of said amplifying means in accordance with a power of the envelope of the telephone current wave, said power being less than unity.

2. In a signaling system, a transmitting station, a source of a telephone current wave of varying volume, means for amplifying and transmitting the wave, means associated with and adapted to modify the amplification factor of said amplifying means in accordance with the envelope of the telephone current wave, means for receiving said modified wave, a translating device associated therewith comprising an amplifier and a detector operated upon directly by the received wave for modifying the amplification factor of the amplifier in accordance with the envelope of the received wave but in the reverse manner from that at the transmitting station.

3. In a signaling system, a transmitting station, a source of a telephone current wave of varying volume, means for amplifying and transmitting the wave, means associated with and adapted to modify the amplification factor of said amplifying means in accordance with the nth power of the envelope of the telephone current wave where n is less than unity, means for receiving said modified wave, a translating device associated therewith comprising an amplifier and means for modifying the amplification factor of the amplifier in accordance with a power of the envelope of the received wave, the power being the reciprocal of the power at the transmitting station.

4. In a signaling system, a source of a telephone current wave of varying volume, means for amplifying the wave, means associated

with and adapted to modify the amplification factor of said amplifying means in accordance with the envelope of the telephone current wave, said means comprising a vacuum tube with a non-linear characteristic and a rectifier connected to the output thereof and associated with the amplifier.

5. In a signaling system with a source of telephone current wave of varying volume, the method of signaling which consists in generating the signal wave comprising the wave in accordance with the nth power of the amplitude of the wave envelope where n is less than unity, transmitting the wave, receiving the wave and expanding it in substantial accordance with the $\frac{1}{nth}$ power of the amplitude of the received wave.

6. In a signaling system, a transmitting station, a source of a telephone current wave of varying volume, means for amplifying and transmitting the wave, means associated with and adapted to modify the amplification factor of said amplifying means in accordance with the envelope of the telephone current wave, means for receiving said modified wave, said means comprising a receiving amplifier, a translating device associated therewith and operated upon directly by the modified received wave and adapted to modify the amplification factor of the receiving amplifier in accordance with a power of the envelope of the received wave, said power being greater than unity.

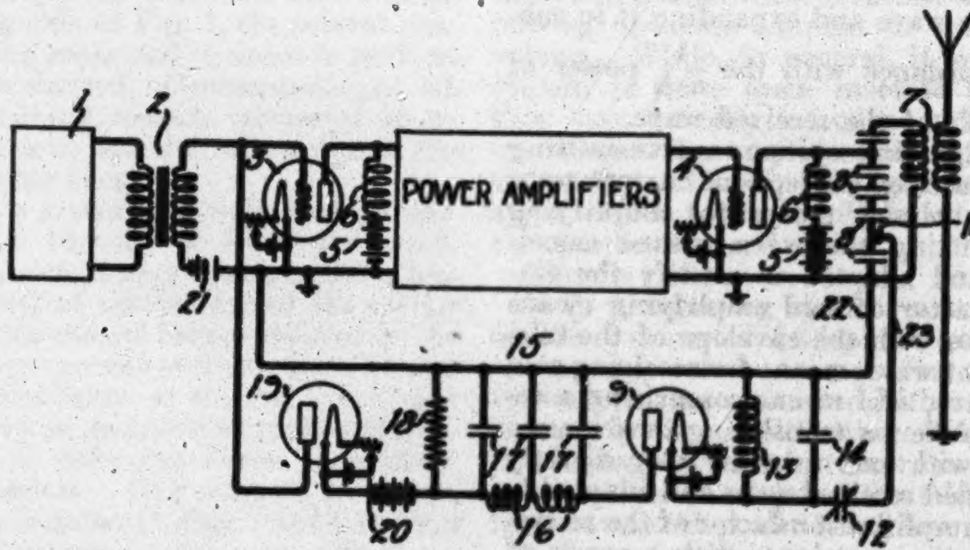
In testimony whereof, I have signed my name to this specification this 3rd day of August, 1926.

ESTILL I. GREEN.

Dec. 15, 1931. J. C. SCHELLENG 1,836,556

REGULATING DEVICE FOR HIGH FREQUENCY POWER AMPLIFIERS

Filed Nov. 4, 1924



Inventor:
John C. Schelleng
by E. W. Adams Atty.

Patented Dec. 15, 1931 1,836,556

UNITED STATES PATENT OFFICE

JOHN C. SCHELLENG, OF MILLBURN, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

REGULATING DEVICE FOR HIGH FREQUENCY POWER AMPLIFIERS

Application filed November 4, 1924. Serial No. 747,799.

This invention relates to amplifying systems and more particularly to devices for limiting the output voltage of such systems.

One object of this invention is to prevent the production of an excessive potential in the output circuit of an amplifying system.

Another object is to control the energy supplied to the input circuit of a power amplifier by voltage changes in its output circuit whereby the potential developed in its output circuit is maintained within a desired safe value.

A feature of this invention is a voltage limiting device so connected between the output and input circuits of a power amplifier, that an excessive voltage in the output circuit reduces the power supplied to the amplifier input circuit.

Novel features which are believed to be characteristic of this invention are pointed out with particularity in the claims appended hereto. The invention itself, however, both as to the details of its organization and its mode of operation, will be better understood by reference to the following description taken in connection with the accompanying drawing in which the single figure is a diagrammatic representation of a radio signaling circuit embodying this invention.

Referring to the drawing, there is shown a modulating system having its output circuit connected by a transformer 2 to the input circuit of a power amplifier. The first and last stages of the power amplifier are represented, by way of example, as space discharge devices 3 and 4 respectively. The modulating system 1 may be of any well known type adapted to produce a carrier wave modulated in accordance with signals. Space current is applied to the discharge devices 3 and 4 by sources 5 through inductances 6 which may be either air core inductances or iron core choke coils. These inductances are used to prevent short circuiting the amplified alternating current through the sources 5. Source 21 is adapted to maintain the grid of repeater 3 at the desired negative potential relative to its cathode. The alternating current anode circuit of repeater 4 includes the primary winding of transformer 7, the secondary of which is connected in the radiating or transmission circuit. Capacity 8 comprising a plurality of units is connected across the primary winding of the transformer 7 and cooperates therewith to constitute a circuit tuned to the frequency of the transmitted wave.

The voltage limiting device includes the rectifier 9, filter15 and rectifier 19. Rectifier 9 is connected across a portion of the tuning capacity. One connection 10 is made variable and may be adjusted to connect one or more of condensers 8 to the rectifier 9 so as to obtain the proper ratio between the voltage produced in the primary winding of transformer 7 and that supplied to the rectifier 9. Variable condenser 12 is inserted in lead 23 from connection 10 for the purpose of adjusting the coupling between the power amplifier output circuit and the voltage limiting device. In connection with condenser 14 it controls the ratio of voltage applied by condenser 8 to that supplied to coil 13. Inductance 13 acts as a by-pass for direct curent, in the circuit including rectifier 9, around condenser 14. Although rectifier 9 has been shown as a two-element space discharge device having a hot cathode and cold anode, any type of device possessing the property of unilateral conductivity can be used.

The alternating current component of the rectified current flowing through the circuit of rectifier 9 is prevented from passing through resistance 18 connected in series with rectifier 9 by means of a filter 15. This filter is shown as comprising series inductances 16 and shunt condensers 17. Inductances 16 will offer high impedance to the alternating current which will be shunted through condensers 17, while direct current will flow in the circuit including rectifier 9 and inductance 13, inductances 16 and resistance 18. The cathode of rectifier 19 is connected through battery 20 and resistance 18 to the cathode of the device 3 while its anode is connected to the grid of device 3 of the power amplifier. Direct current will flow through resistance 18 in such a direction that the terminal of this resistance connected to the cathode of rectifier 19 will tend to have a nega-

tive potential. Rectifier 19, battery 20 and resistance 18 constitute a circuit connected across the grid-cathode circuit of the first power amplifier tube 3 in shunt to the secondary of transformer 2. When the impedance of rectifier 19 is lowered by its cathode becoming negative with respect to its anode, current will flow therethrough so that the potential applied to the grid of device 3 cannot build up beyond a predetermined value.

In the operation of this system the voltage limiting device will be isolated from the input circuit of the first power amplifier tube when the cathode of rectifier 19 is positive with respect to its anode due to the unilateral impedance introduced thereby. When a voltage in excess of a predetermined value is impressed upon the condensers 8 in the output circuit of the power amplifier, current will flow through the rectifier 9 and resistance 18. When the current flowing through the resistance 18 reaches such value that the cathode of rectifier 19 is made negative with respect to its anode the impedance of the rectifying device 19 will be reduced, thereby causing the device to act as a load in shunt to the input or cathode-grid circuit of the first stage 3 of the power amplifier. A certain amount of the input energy supplied by the transformer 2 will be diverted through this shunt path and hence the control potential impressed upon the grid of the device 3 is prevented from building up. The voltage of battery 20 should be adjusted to a value such that the potential applied to the rectifier 19 due to the voltage drop across the resistance 18 will be sufficient to cause the cathode to become negative with respect to its anode when the voltage in the output circuit of the amplifier across the capacity connected to the rectifier 9 reaches the predetermined value. By adjusting tap 10 the limiting or protective device may be set to exercise its control at various voltage levels of the amplifier output.

Although this invention has been shown and described as embodied in a particular circuit, it is understood that it is of general application, and hence is not to be limited to the specific details herein disclosed.

What is claimed is:

1. A space discharge amplifying system including an input circuit for said system and an output circuit therefor, a circuit interconnecting said input and output circuits including a non-conductive impedance comprising means for establishing a conductive path through said impedance for a portion of the input energy when the output voltage of the system exceeds a predetermined value.

2. An electrical system comprising an amplifier having wave input and output circuits, a regulating circuit interconnecting said input and output circuits, a space discharge rectifier connected in shunt to said input circuit and included in said regulating circuit, and means for controlling the impedance of said rectifier in accordance with the wave voltage in said output circuit whereby the input energy of the waves impressed upon the amplifier is controlled.

3. In an electrical system, an amplifier, an input circuit for said amplifier and an output circuit for said amplifier, a voltage limiting circuit connecting said input and output circuits and including a rectifier connected to said input circuit and a rectifier connected to said output circuit, the rectifier connected to said input circuit being of normally high impedance, and means whereby said rectifier is rendered of low impedance by the application of a potential exceeding a certain predetermined value upon the rectifier connected to said output circuit.

4. In an electrical system, an amplifier comprising space discharge repeaters having input and output circuits, a voltage limiting device comprising a plurality of rectifiers, means for impressing a voltage derived from said amplifier upon one of said rectifiers, a filter comprising inductance and capacity for preventing alternating currents from passing to said second rectifier, means for applying a voltage to said second rectifier varying in proportion to the voltage impressed upon said first mentioned rectifier, means for causing said second rectifier to act as a load on said amplifier when the output potential of said amplifier exceeds a certain predetermined value.

5. A system comprising an electron discharge device amplifier having an input circuit and an output circuit, an auxiliary space discharge device associated with said input circuit, and means cooperatively associated with the output circuit whereby excessive potential differences across an element of said output circuit reduce the input energy applied to said amplifier by acting upon the input circuit to establish a conductive path in shunt thereto.

6. In an electrical system, an amplifier comprising space discharge devices, an input circuit and an output circuit for said amplifier and a circuit interconnecting said input circuit and said output circuit, said interconnecting circuit including rectifiers and a resistance for preventing the output energy level of said amplifier exceeding a predetermined value.

7. A space discharge amplifying system provided with an input circuit and an output circuit, a normally open circuit for connecting said input circuit with said output circuit including a variable impedance, and means, responsive to energy in said output circuit, for closing said connecting circuit and inserting said variable impedance in shunt to said input circuit.

8. In an electrical system, a space discharge amplifier, an input circuit and an output cir-

cuit for said amplifier, a variable impedance and means controlled by the output energy of the amplifier to insert said impedance in shunt to said input circuit to control the ratio of the energy supplied to the input circuit with respect to the energy applied to the amplifier.

9. In an electrical system, a space discharge amplifier, an input circuit and an output circuit for said amplifier, and a circuit interconnecting said input and output circuits including two rectifiers and a resistance which cooperate to control the amplifier.

10. An amplifier having an output circuit and an input circuit, means connected to said output circuit to regulate the energy applied to said input circuit in such manner as to prevent excessive currents in said output circuit and means for rendering said regulating means ineffective to regulate said input energy so long as said output current is less than a predetermined magnitude.

11. An amplifier having an input circuit and an output circuit and means associated with said output circuit for diverting energy from said input circuit when the magnitude of said output circuit current exceeds a preassigned value, said means remaining ineffective so as to permit said amplifier to operate unaffected by it throughout any range of magnitude of output currents less than said preassigned value.

12. A system comprising a space discharge amplifier having an input circuit, an output circuit, a conductive path of variable impedance in shunt to said input circuit and means associated with said output circuit and responsive to potential differences across an element thereof to vary the impedance of said conductive path in accordance with said potential differences without, however, in any way affecting said impedance while the output circuit currents lie within any range less than a preassigned limiting magnitude.

13. In combination, an amplifier, an input circuit connected thereto, an output circuit connected thereto, a path connected in shunt across said input circuit having a normal impedance which is substantially infinite and means operated in response to excess currents in said output circuit to vary the magnitude of said impedance so as to cause it to variably divert energy from said input circuit.

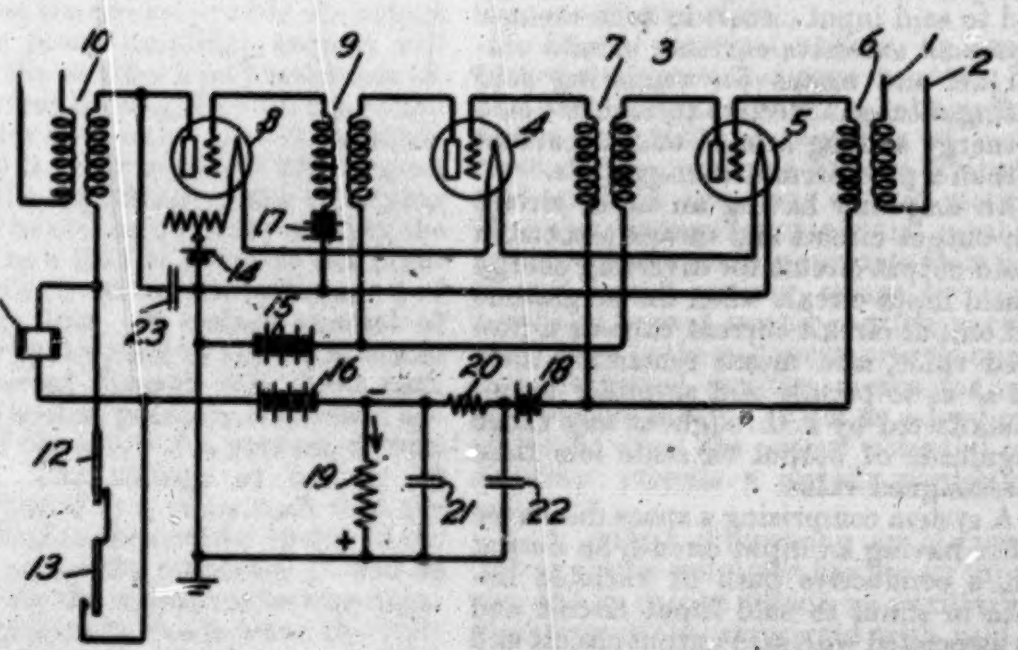
In witness whereof, I hereunto subscribe my name this 3rd day of November A. D., 1924.

JOHN C. SCHELLENG.

July 26, 1932. P. H. EVANS 1,869,323

COMMUNICATION SYSTEM

Original Filed Sept. 24, 1923



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Patented July 26, 1932 1,869,323

UNITED STATES PATENT OFFICE

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COMMUNICATION SYSTEM

Original application filed September 24, 1923, Serial No. 664,432, now Patent No. 1,736,852, and in Germany August 15, 1924. Divided and this application filed October 18, 1929. Serial No. 400,540. Renewed March 25, 1932.

This invention relates to carrier wave communication systems and particularly to the control of the transmission level in carrier wave systems.

The application is a division of original application Serial No. 664,432, filed September 24, 1923, patented November 26, 1929, #1,736,852.

One object of the invention is to provide a repeating circuit employing thermionic vacuum tubes that shall gradually and continuously vary the impedance of one of the tubes in an improved manner without any moving parts to control the gain in transmission level.

Another object of the invention is to provide a repeating circuit of the above indicated type that shall control the amplifying factor of one tube according to the output current of another tube without generating undesired oscillatory currents.

A further object of the invention is to provide a carrier wave receiving circuit having space discharge devices connected in tandem to an incoming line that shall control the impedance of one of the devices according to the output of another device and prevent generation of spurious oscillations.

In repeating circuits and in carrier wave receiving circuits it is desirable to control the energy level transmitted to the receiving apparatus. The control of the energy level should be gradual and continuous without generating any undesirable oscillatory currents.

The present invention is illustrated by means of a receiving circuit for a carrier wave transmission system. Two three-element thermionic amplifier tubes and a detector or rectifier tube are connected in tandem to an incoming line. The incoming line supplies carrier waves of widely differing intensity to the amplifier tubes for calling and communication purposes.

A resistance element which is included in the output circuit of the rectifier or detector tube is also included in the grid circuit of the two amplifier tubes. The resistance element thus impresses a potential on the grids of the amplifier tubes which varies according to the output from the rectifier or detector tube. A condenser is shunted across the anode and cathode of the rectifier or detector tube to by-pass any carrier frequency waves which may pass through the detector tube. A filter element comprising condenser and resistance elements is connected across the gain control resistance element for shunting speech frequency variations to prevent the amplifier tubes from setting up spurious oscillations. If the filter were not connected across the gain control resistance element, undesirable oscillations might be amplified to cause so-called singing.

The single figure in the accompanying drawing is a diagrammatic view of a receiving channel provided with a gain control circuit constructed in accordance with the invention.

Referring to the drawing an incoming line comprising conductors 1 and 2 supplies carrier waves of varying amplitude to an amplifier 3 comprising space discharge devices 4 and 5. The incoming line is connected to the space discharge device 5 by means of a transformer 6 and the space discharge device 5 is connected to the device 4 by means of a transformer 7. Each of the devices 4 and 5 comprises an anode, a cathode and a grid or control element.

A detector or rectifier space discharge device 8 is connected to the output circuit of the space discharge device 4 by means of a transformer 9. The output circuit of the detector tube 8 is connected by a transformer 10 to an operator's telephone set (not shown) or by a relay 11 to a selective calling means (not shown). Switch elements 12 and 13 provide a shunt circuit around the relay 11 when the operator's telephone set is in service. Inasmuch as the invention is not concerned with the operation of the selective calling circuits and the operator's telephone set, a detailed description and illustration thereof is deemed unnecessary. The calling circuits and the operator's telephone set are fully illustrated in the original application Serial No. 664,432, filed September 24, 1923.

A battery 14 is provided for supplying heating current to the filaments of the space

discharge devices 3, 4 and 5. A battery 15 is provided for supplying plate potential to the space discharge devices 4 and 5 and a battery 16 is provided for supplying plate potential to the dectector or rectifier discharge device 8. A battery 17 supplies negative grid potential to the detector or rectifier device 8 and a battery 18 supplies negative grid potential to the space discharge devices 4 and 5.

A resistance element 19 in the output circuit of the detector or rectifier space discharge device is also included in the grid circuits of the space discharge devices 4 and 5. Thus, a negative potential is impressed on the grids of the discharge devices 4 and 5 which varies in accordance with the space current of the detector or rectifier space discharge device. A filter comprising a resistance element 20 and condensers 21 and 22 is connected across the resistance element 19 for shunting voice frequency variations to prevent the amplifier 3 and the detector or rectifier acting as an oscillation generator. The filter insures against the generation of spurious oscillations which would cause the so-called "singing". The filter also serves to adjust the time constant of the circuit to the desired value. A condenser 23 is connected between the plate and filament of the detector or rectifier space discharge device 8 to bypass any high frequency carrier waves which may pass through the detector or rectifier discharge device.

The carrier waves of varying amplitude supplied by the incoming line comprising conductors 1 and 2 are amplified by the discharge devices 4 and 5 and rectified by the discharge device 8. The output circuit of the discharge device 8 may be traced from the plate of the device 8 through the primary winding of the transformer 10, relay 11, battery 16, gain control resistance 19 and ground to the filament of the discharge device 8. It is thus apparent that a potential is impressed across the gain control resistance 19 which varies according to the output from the detector or rectifier discharge device 8. The gain control resistance element 19 is also included in the input circuits to the amplifier space discharge devices 4 and 5.

The input circuit for the discharge device 5 may be traced from the grid of the device 5 through the secondary winding of the transformer 6, grid biasing battery 18, filter, the gain control resistance element 19 and ground to the filament of the discharge device 5. The input circuit for the space discharge device 4 is traced in a like manner through the secondary winding of the transformer 7. It is thus apparent that an increase in the space current of the detector or rectifier discharge device 8 will increase the negative potential impressed on the grids of the amplifier discharge devices 4 and 5. This will serve to reduce the amplitude of the waves supplied to the detector or rectifier discharge devices and accordingly control the power supplied to the operator's telephone set (not shown).

It is apparent that the grid of the detector or rectifier discharge device 8 may also be connected to the same terminal of the grid biasing battery 18 as the grids of the amplifier discharge devices 4 and 5 are connected. Moreover, the grid of the detector or rectifier discharge device 8 may alone be thus connected and the grids of the discharge devices 4 and 5 may be connected to ground through an invariable biasing battery.

Modifications in the system and in the arrangement and location of parts may be made within the spirit and scope of the invention and such modifications are intended to be covered by the appended claims.

What is claimed is:

1. In a repeater system, a plurality of space discharge repeaters arranged in tandem, an anode-cathode circuit for one of said repeaters including a resistance, said resistance being included in the grid cathode circuit of a second one of said repeaters for controlling the gain of the second repeater, and means for shunting said resistance element to adjust the time constant of the gain control circuit.

2. In a signal system, a plurality of space discharge tubes arranged in tandem, each of said tubes having a grid, an anode and a cathode, an anode-cathode circuit for one of said tubes including a resistance element, said resistance element being included in the grid-cathode circuit of another of said tubes, and a filter element connected across said resistance element for shunting alternating currents to prevent singing condition in the system.

3. In a carrier wave receiving system, two high-frequency amplifier tubes and a rectifier tube connected in tandem to an incoming line, each of said tubes comprising a grid, a cathode and an anode, and a resistance element connected in the output circuit of said rectifier tube and the input circuits of the two amplifier tubes for gradually and continually governing the amplifying power of said amplifier tubes according to the output current from said rectifier tube.

4. In a signal system, a plurality of space discharge tubes arranged in tandem, each of said tubes having a grid, a cathode and an anode, one of said tubes serving as a detector, a resistance element in the output circuit of said detector tube, said resistance element being included in the grid-cathode circuit of another one of said tubes to form a gain control circuit, and a filter element connected to said resistance element for preventing generation of undesired oscillatory currents in the system and for adjusting the time constant of the gain control circuit.

5. In a repeater system, a plurality of space discharge repeaters arranged in tandem, an anode-cathode circuit for one of said repeaters including a resistance, said resistance being included in the grid cathode circuit of another of said repeaters, and a filter element connected across said resistance consisting of capacity and resistance elements adapted to shunt around said resistance alternating currents whereby the setting up of continuous oscillations in said repeater system is prevented.

6. In a carrier wave receiving system, two high-frequency amplifier tubes and a rectifier tube connected in tandem to an incoming line, each of said tubes comprising a grid, a cathode and an anode, a resistance element connected in the output circuit of said rectifier tube and in the input circuit of one of said amplifier tubes for gradually and continually governing the amplifying power of the system according to the output current from said rectifier tube, and a filter element connected across said resistance element for shunting alternating currents to prevent singing condition in the system.

7. In a carrier wave receiving system, a high frequency amplifier tube and a detector tube connected in tandem to an incoming line, each of said tubes comprising a grid, a cathode and an anode, a resistance element connected in the output circuit of said detector tube and in the input circuit of said amplifier tube for gradually and continually governing the amplifying power of the system according to the output current from said rectifier tube, a condenser connected between the anode and cathode of said detector tube for by-passing carrier frequency waves, and a filter element comprising capacity and resistance elements connected across said first mentioned resistance element for shunting alternating currents to prevent singing condition in the system.

8. In a signal system, a space discharge device provided with input and output circuits and adapted to have relatively low frequency currents and a high frequency carrier current in the output circuit, a resistance element included in the output circuit, means for governing the input level to said device according to the potential across said resistance element, and a filter connected across said resistance element for shunting the low frequency currents.

9. In a signal system, a space discharge device provided with input and output circuits and adapted to have currents of different frequencies in the output circuit, a resistance element included in the output circuit, means for governing the input level to said device according to the potential across said resistance element, and selective means for limiting the control of the potential across said resistance element to a restricted frequency range of the currents in the output circuit of said device.

10. A gain control circuit comprising in combination, an amplifier having a grid-cathode circuit, a rectifier connected in tandem with said amplifier, a resistance element carrying rectified current from said rectifier, means for connecting said resistance element to said grid cathode circuit of the amplifier to control the gain of the amplifier, and means for shunting said resistance element to control the time constant of the gain control circuit.

11. A gain control circuit comprising in combination, a repeater having a grid-cathode circuit, a rectifier connected in tandem with said amplifier, a resistance element carrying rectified current from said rectifier, said resistance element being included in the grid-cathode circuit of said repeater to control the gain of the repeater, and a filter element connected to said resistance element for preventing the generation of undesired oscillatory currents in the system and for adjusting the time constant of the gain control circuit.

12. A gain control circuit comprising in combination, an amplifier having input and output circuits, a rectifier connected to the output circuit of said amplifier, a resistance element in circuit with said rectifier, said resistance element being included in the input circuit of said amplifier, and a filter connected in shunt to said resistance element for preventing generation of undesired oscillatory currents in the system and for adjusting the time constant of the gain control circuit.

In witness whereof, I hereunto subscribe my name this 15th day of October, 1929.

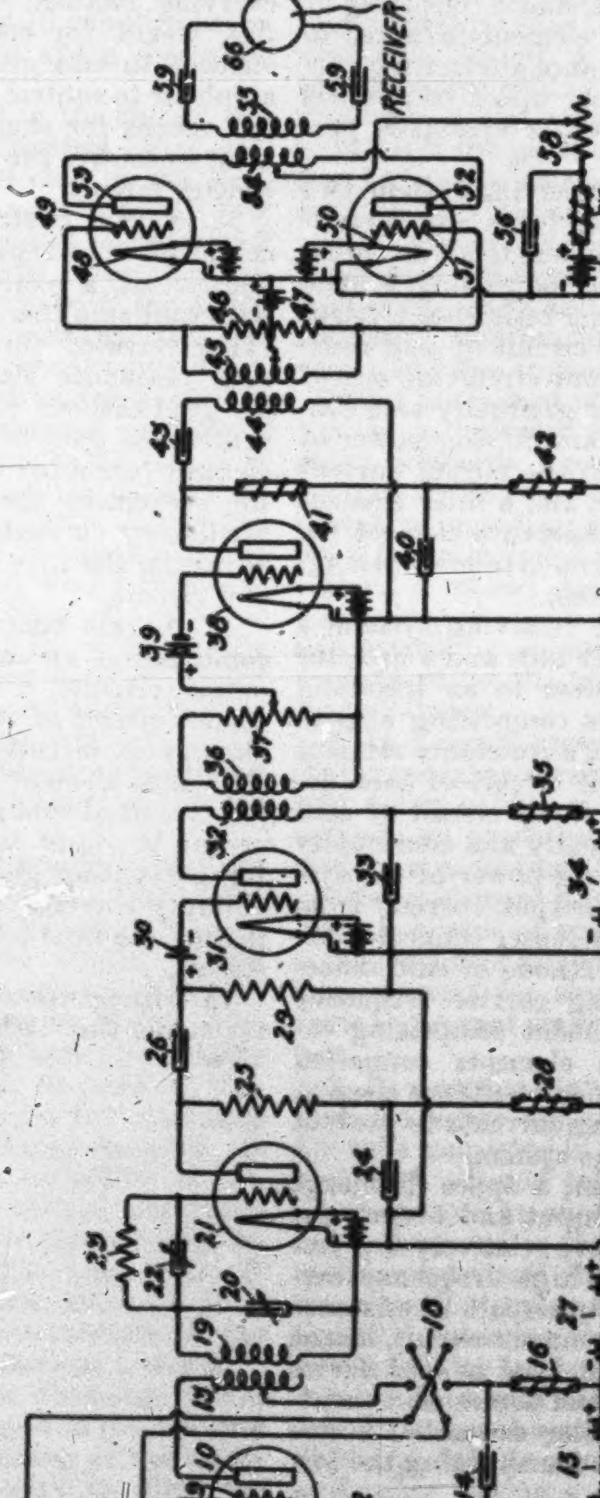
PORTER H. EVANS.

Aug. 12, 1924. 1,504,537

H. DE F. ARNOLD

POWER LIMITING AMPLIFYING DEVICE

Original Filed Sept. 3, 1915



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Patented Aug. 12, 1924. 1,504,537

UNITED STATES PATENT OFFICE.

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POWER-LIMITING AMPLIFYING DEVICE.

Application filed September 3, 1915, Serial No. 48,873. Renewed September 14, 1922. Serial No. 588,285.

To all whom it may concern:

Be it known that I, HAROLD DE FOREST ARNOLD, a citizen of the United States, residing at Maplewood, in the county of Essex and State of New Jersey, have invented certain new and useful Improvements in Power-Limiting Amplifying Devices, of which the following is a full, clear, concise, and exact description.

This invention relates to power limiting repeating and amplifying devices, and especially to devices of this kind which are adapted to be used in radio communication systems for limiting the electrical power which may be transmitted to a receiving instrument in such a system, and more particularly to devices in which such limiting action is obtained by utilizing the properties of thermionic or equivalent discharge devices.

An object is to provide rapidly responsive means by which a definite upper limit is set upon the amount of power which may be communicated to a receiving circuit or apparatus, while amounts of power below said limit may be transmitted without interference.

The ability to secure such limitation is desirable, in a radio receiving system for example, because foreign disturbances, which in the wireless are often of large magnitude compared with that of the received signals, may be reduced to a value not exceeding that of the signals, thus securing higher intelligibility in reception.

In a general aspect, the object of this invention is to provide improved circuits and means for association with thermionic repeating devices. The objects of the invention may be accomplished by the apparatus herein disclosed wherein, unilaterally conducting elements, placed in opposition in a circuit, limit the current which may flow in either direction around that circuit, and in this respect this invention is similar to that which forms the subject of my Patent No. 1,168,270 for a protection device for electric circuits, granted January 18, 1916. It differs from that, however, in that additional elements are associated with the unilateral devices, and elsewhere, to secure certain improvements in operation, as explained later in this specification, and also in that an amplifying effect is obtained which makes this device particularly applicable in radio communication.

In the preferred form of this device the unilateral conductivity is secured by causing part of the circuit to lie in the paths of thermionic currents between hot cathodes and cold anodes, said thermionic currents being oppositely directed with respect to said circuit. These thermionic currents are caused to flow by impressing upon their limiting electrodes, in multiple, an electromotive force operating through a high impedance, said high impedance performing an important function in connection with the power or current limiting action of the device as hereinafter described. This high impedance serves to differentiate this power limiting device from the repeating device described in U. S. Patent No. 1,128,292, to E. H. Colpitts for an electric wave amplifier, as will be apparent from the further explanation of its function given later.

The nature of this invention will be more fully understood by reference to the drawing, which represents a receiving system for radio communication embodying this invention, and in which 1 represents an elevated receiving conductor, 2 a tuning inductance coil, 3 an adjustable condenser, and 4 an adjustable resistance shunting the condenser. By means of the coil 5, the tuned circuit 5, 6 is coupled to the antenna. The terminals of the condenser 6 are connected to the input circuit of the thermionic repeater 7, comprising heated filament 8, grid 9 and plate 10. A battery 11 is preferably connected in the input circuit to maintain the grid at a negative potential with respect to the filament. 12 is a battery which serves to heat the filament 8. The output circuit of repeater 7 contains battery 15 and a choke coil 16, shunted by a condenser 14 to afford a path for high frequency power, and the coils 13 and 17, the latter having reversible inductive connection with coil 5, the sense of its inductive action being controlled by reversing switch 18. The purpose of coil 17 is to neutralize the coupling

between input and output circuits of the amplifier 7 and thus prevent free oscillation or "singing." The coil 19, coupled to 13, connects the above described amplifying circuit to the tuned circuit 19, 20. Across the terminals of condenser 20 is connected the input circuit of a detecting device which comprises thermionic element 21, condenser 22 and resistance 23. The purpose of the combination of the condenser and high resistance in connection with thermionic element 21 is as follows: When a positive charge, for example, is forced upon the grid of element 21, this charge is neutralized by electrons from the filament. Then when, in the next alternation, a negative charge is forced to the grid by the incoming wave, this charge adds to that already present and produces a still larger negative charge upon the grid, since a negative charge cannot be neutralized by the electron stream. The condenser therefore aids in decreasing the average current in the output circuit. The grid must, however, be conductively connected to the incoming circuit, otherwise the accumulated negative charge would remain and prevent further operation. To provide for this, a high resistance leakage path is shunted around the condenser to allow a leak which is slow compared with the period of high frequency currents, but still rapid enough to permit considerable leakage in a time comparable with the period of telephonic waves. The output circuit of this thermionic element is supplied with current by batteries 15 and 27, acting through choke coil 28 and resistance 25, condenser 24 serving as a high-frequency shunt, and condenser 26 to limit the direct current to the detector circuit. 31 is an amplifier having a battery 30 in series with its grid and a resistance 29 across its input circuit. The output circuit of amplifier 31 comprises a battery 34 and choke coil 35, both shunted by condenser 33, and a coil 32. Coil 36, coupled with 32, supplies power to resistance 37, across a portion of which is connected the input circuit of another amplifier 38, having a battery 39 in its grid circuit. The output circuit of amplifier 38 is supplied by battery 34 and contains choke coil 42, condenser 40 and coil 41, whose functions are the same as those of the corresponding elements in the previous amplifier. It also contains condenser 43 and coil 44. The apparatus to the right of 44 comprises the power-limiting device and the receiving circuit.

In this device coil 45 is coupled to coil 44. 46 is a resistance. 48, 49 and 53 are the filament, grid and plate, respectively, of a structure of the audion type, as are also 50, 51, 52, respectively. 47 is a battery common to the input circuits of the two structures, which structures may be in the same vessel or in separate vessels. 54 is a transformer winding connecting plates 52 and 53 and having a connection brought out at its middle point. The secondary winding 55 of this transformer leads to a receiving instrument 66, preferably through the condensers 59.

Current is supplied to the output circuits of the last mentioned structures of the audion type by battery 65 connected through coil 57, and the variable high resistance 58 to the middle point of coil 54 and to the common point of the two filaments 48 and 50. Condenser 56 and choke coil 57 tend to prevent fluctuations of current from the source 65 from passing through the thermionic elements and coils 54. The receiving set is grounded at the points 60, 61, 62, 63 and 64.

The operation of this system is as follows: Power received by the antenna is transferred to the circuit 5, 6, augmented by amplifier 7, communicated to circuit 19, 20, transformed into low frequency form by detection in element 21, augmented by amplifiers 31 and 38, and passed to the receiving instrument through the power limiting device whose operation will now be explained.

The thermionic repeater being unilaterally conducting, the repeater element 48, 49, 53 can transmit positive current due to battery 65, only in the direction from 53 to 48. Also, element 50, 51, 52 can transmit positive direct current only in the direction from 52 to 50. If these currents are approximately equal, it follows that the maximum variation in current around the circuit 48, 53, 54, 52, 50 can never exceed the magnitude of the normal current in either element, provided none of this varied current can pass through that part of the circuit of the battery 65 which is common to the two thermionic elements. To prevent any appreciable passage of variable current the high resistance 58 is used.

The variations in the normal currents in the winding 55, which variations constitute the signals to be received, are produced in the usual way by the action of the grids 49 and 51, across which the signal voltage is impressed, so that it is obvious that an impressed voltage of large value, tending to produce a large variation of current in the power limiting device, cannot cause an alternating or varying current in winding 55 larger than the normal space current of the elements. This normal space current is adjusted until its value is just greater than the amplitude of the signals to be received.

The resistance 58 prevents serious unbalance of currents in the two halves of winding 54, when a large electromotive force is impressed, by lowering the effective potential difference between plate and filament by the amount of the voltage drop in the

said resistance, and consequently decreasing the current which can flow in the output circuit of either repeater element, this effect being a fundamental one in the operation of the thermionic repeater.

Owing to the fact that the vacuum tube repeaters can transmit current in one direction only, it is impossible to do more by any impulse than to decrease the current in one vacuum tube repeater to zero. The current in the other tends to increase in accordance with the increase of potential on the grid.

The total drop of potential in the output circuit is made up of two parts, that across the tube between the anode and cathode and that across the resistance 58.

If now the current is increased, not by increasing the electromotive force of the battery or source 65, but by increasing the potential difference between the cathode and the grid, the current through the resistance 58 increases. Since the output source 65 remains constant, it follows that the drop of potential across the tube decreases while that across the resistances 58 increases. A choking effect is thus produced by the resistance 58 with the result that, as the grid potential becomes greater, more and more current is diverted to the grid. A point is finally reached where no measurable increase in anode-cathode current is produced by increasing the grid potential. If the maximum amount of current is made approximately equal to the current required to transmit the talk, the interfering sounds, due to accidental causes, cannot possibly be of greater intensity than the speech.

What is claimed is:

1. A receiving system for radio communication comprising an antenna, a tuned receiving circuit connected therewith, means for amplifying the power of waves communicated to said tuned circuit, means for detecting said waves of amplified power, means for amplifying said detected waves, translating means responsive to said detected waves, and means including thermionic elements for limiting the power transmitted by said waves to said translating device.

2. In combination with a source of power, a power limiting device comprising electric discharge devices each including an impedance controlling element, said devices having divided input and divided output circuits, a connection of said input circuit to said source of power, a high impedance path containing a source of electromotive force and connected between the points of division of said divided circuits, a receiving device and transformer windings for connecting said output circuit to said receiving device.

3. A receiving system for radio communication comprising an antenna, a receiving circuit connected therewith, means for amplifying the power of waves communicated to said circuit, means for detecting said amplified waves, means for amplifying said detected waves, translating means responsive to said detected waves, and a power limiting device comprising a thermionic repeater with divided input and divided output circuits, a high impedance path containing a source of electromotive force connected in the output circuit of said repeater and transformer windings for connecting said output circuit to said translating means.

4. In a power limiting device, the combination of a plurality of evacuated vessels each including a unilaterally conductive space, an impedance controlling element for said space, said spaces being connected in opposition in a circuit, a high impedance path and a source of constant electromotive force in said path, said elements being supplied with current in multiple through said path, auxiliary electrodes for varying said currents in response to an impressed voltage, a receiving circuit and means for communicating variations in said currents to said receiving circuit.

5. A receiving system comprising two electron discharge devices, each of said devices including an impedance controlling element, individual input circuits and individual output circuits for said devices, a portion of the similar circuits of said devices being in common, and a high impedance in the said common portion.

6. In a receiving system for radio signaling, a power limiting device comprising separated elements, an impedance controlling means for controlling the impedance of the space between said elements, said device having input and output circuits, a source of current for said output circuit, and regulating means in the output circuit for causing the current supplied by said source to approach a maximum value as the input voltage is increased.

7. In a receiving system for radio signaling, a power limiting device comprising separated electrodes, an impedance controlling means for controlling the impedance between said electrodes, said device having input and output circuits, a source of power for said output circuit, and means responsive to the current in said output circuit for controlling the potential applied from said source across said electrodes whereby the rise of currents in said output circuit is limited.

8. In a receiving system for radio signaling, a power limiting device comprising an electron discharge element, an input circuit and an ouput circuit for said element, said output circuit having a portion which is traversed by fluctuating current passed by said element, and a high resistance in said portion.

9. In a receiving system for radio signaling, a power limiting device comprising an electron discharge element, an input circuit and an output circuit having a portion which is traversed by fluctuating current passed by said element, a source of current for said output circuit, and a high resistance in said portion serially connected with said source for limiting the rise of current in said output circuit.

10. A receiving system for radio communication comprising an antenna, a receiving circuit connected therewith, means for detecting the waves communicated to said circuit, translating means responsive to said detected waves, and a device for limiting the power transmitted by said waves to said translating means; said device comprising an electron discharge device, a source of current therefor, and means for determining the intensity of the effect produced in said translating means by a signal wave of a certain intensity and for preventing waves of greater intensity from exceeding said effect.

11. In a power limiting device, the combination of electron discharge devices each including an impedance varying element connected in opposition in a circuit, said elements having input and output circuits, means for supplying current to said output circuits, means for preventing fluctuating currents from passing through said supplying means, and means for regulating the maximum value of the current furnished by said supplying means.

12. In a combination with a source of power, a power limiting device comprising electron discharge repeaters with divided input and divided output circuits, a connection of said input circuit to said source of power, a path connected between the points of division of said circuits; said path comprising a source of electromotive force, means for preventing fluctuating currents from passing through said source, and means for regulating the maximum value of the current supplied from said source; a receiving device, and transformer windings for connecting said output circuit to said receiving device.

13. In combination with a source of power, a power limiting device comprising electron discharge repeaters with divided input and divided output circuits, a connection of said input circuit to said source of power, a path connected between the points of division of said circuits; said path comprising a source of electromotive force, an impedance device for preventing fluctuating currents from passing through said source, and a resistance for regulating the maximum value of the current supplied from said source; a receiving device, and transformer windings for connecting said output circuit to said receiving device.

14. The combination of a receiving system comprising two electron discharge devices each including an impedance varying element, each having an input circuit and an output circuit, a portion of said output circuits being in common, and a high impedance in the common portion of said output circuits.

15. In combination, a plurality of electronic discharge devices, each of said devices having an impedance varying element for influencing the space current flow therethrough in accordance with waves impressed thereon, a source of space currents for said devices, and means tending to maintain the sum of the space currents through said devices constant.

16. In combination, a plurality of electrical circuits each of said circuits including a conductive space, means including impedance varying elements for causing the impedance of said spaces to vary differently at different instants, a current supply source for said circuits, and means associated therewith tending to keep the sum of the currents through said circuits constant.

17. An amplifier comprising two electrical discharge devices, input and output circuits therefor, said devices being symmetrically and oppositely disposed with respect to each of said circuits, space current paths for said devices, said paths having a common external portion of high impedance.

18. An amplifier comprising two electrical discharge devices, input and output circuits therefor, said devices being symmetrically and oppositely arranged with respect to each of said circuits, space current paths for said devices, a source of space current therefor, said paths having a common external portion, and means associated with said source for preventing fluctuating currents therethrough.

19. An amplifier comprising two space discharge devices, input and output circuits therefor, said devices being symmetrically and oppositely arranged with respect to each of said circuits, space current paths for said devices, said paths having a common external portion and a resistance in said portion which is large as compared with the normal impedance of the conductive space of one of said devices.

20. A repeater comprising two electric discharge devices each having a cathode, an anode and an impedance varying element, a connection between said impedance varying elements, a connection between said cathodes, a connection between said anodes, an electrical impedance in one of said connections an electrical impedance in another of

said connections, other connections from intermediate portions of each of said impedances to one of said first mentioned connections, one of said last named connections being provided with a source of current, and means tending to maintain a constant supply from said source.

21. In a repeater, two oppositely disposed electric discharge devices, impedance varying elements for said devices, means for causing one of said elements to increase the impedance of one of said devices, and the other of said elements to decrease the impedance of the other of said devices simultaneously, and means to cause the changes of current through said devices to be simultaneously substantially equal and opposite respectively when said repeater is repeating alternating current.

22. In a signaling system, a power limiting device comprising an electron discharge device having an input circuit and an output circuit, a source of variable current connected to said input circuit, a path in said output circuit through which amplified variations from said source are constrained to pass, and a resistance located in said path of such a value that waves of a normal value from said source will produce desired variations of current through said path, but impulses of a greater voltage will produce current having a maximum value not materially greater than the maximum value of current produced by waves of normal voltage applied to said input circuit.

23. In a signaling system, a power limiting device comprising an electron discharge device having input and output circuits, a source of space current for said output circuit, a path in said output circuit through which alternating current components are constrained to flow and a resistance in said path, said source and said resistance being of such values that incoming signal waves will produce desired changes of current, but incoming waves of greater strength will produce only negligibly larger changes of current through said path.

24. A system for repeating alternating current comprising a plurality of electron discharge devices, an impedance varying element for one of said devices, a source of space currents for said devices, means tending to maintain the sum of the space currents through said devices constant, and means for utilizing the repeated alternating current.

25. A system for amplifying alternating or fluctuating current energy comprising two electrical discharge devices, input and output circuits therefor, said devices being symmetrically and oppositely disposed with respect to each of said circuits, and space current paths for said devices, said paths having a common portion external to said devices and of high impedance to currents of the frequencies to be amplified.

26. A receiving system comprising an electron discharge element, an input circuit and an output circuit for said element, said output circuit having a portion through which the fluctuating component of the current in said output circuit passes, said portion being of relatively high impedance to the fluctuating component.

27. An amplifier comprising two electron discharge devices, an electron emitting cathode and an anode for said devices, space current circuits for said devices, said circuits having a common portion and individual portions, and a high impedance in said common portion.

28. In combination, a source of current, a plurality of electron discharge devices having space current paths, said paths being similarly connected to said source, one of said devices having an impedance varying element, and means tending to maintain the sum of the space currents through said devices constant.

29. The method of overcoming the effects of static disturbances in a wireless signaling system which consists in producing at a receiving station by means of the signaling current an alternating current having a frequency much lower than the transmitted radio frequency current, and passing this current through a circuit containing a device for limiting the energy passing therethrough to a predetermined value.

30. The method of overcoming the effects of static disturbances in a wireless telephone receiving system which consists in first detecting the received signaling waves, thereby producing a varying current having a frequency much lower than the received waves, passing this current through a circuit containing a device for limiting the energy passing therethrough to a predetermined value and reproducing the telephone signal by the current passed through said circuit.

31. The method of reducing detrimental effects of disturbing waves superimposed on waves to be received at a receiving station which comprises utilizing the energy of the received waves to produce a current which varies in amplitude at a frequency widely different from that of the received waves, and passing this current through a circuit containing a device for limiting the energy passing therethrough to a predetermined value.

32. A system for reducing the detrimental effects of disturbing waves superimposed on waves to be received which comprises devices for producing at a receiving station by means of the received waves an alternating current of a widely different frequency from that of the received waves, a circuit through

which the alternating current is to be passed, and means for limiting to a predetermined value the energy passing through said circuit.

33. In an electric system, an incoming circuit and a plural stage amplifier for amplifying signals from said circuit comprising in one stage of said amplifier two vacuum tube repeaters connected in push-pull relation, and at least one stage consisting of a single vacuum tube amplifier feeding into said push-pull stage.

34. In an amplifying system in which the amplitude of the current increases in succeeding stages, a current responsive device actuated by the energy from said system, at least one preliminary amplifying stage consisting of a single vacuum tube amplifier circuit, and a succeeding stage for delivering the amplified current to said responsive device, said last mentioned stage comprising a pair of vacuum tube amplifiers connected in push-pull relation.

35. In a plural stage amplifier circuit for amplifying signal currents, employing vacuum tube amplifiers in which, for relatively strong output currents at least, as the amplitude of the repeated wave becomes larger the distortion of the wave increases, said amplifier circuit comprising at least one stage consisting of a single vacuum tube repeater operating over a relatively small current amplitude range and giving amplification with the required degree of faithfulness of repetition of the signal and a stage into which said single tube stage feeds, for amplifying the repeated wave up to a current amplitude at which undesired distortion would take place in a single one of said tubes used alone, said later stage comprising a pair of vacuum tube repeaters connected in push-pull relation, whereby at said large current amplitude a faithfulness of repetition is obtained consistent with that of the preceding stage.

36. In combination, three electron discharge tubes, means for supplying discharge current to said tubes, two of said tubes being connected in push-pull relation, the other one of said tubes being arranged to impress amplified signal waves on said push-pull connected tubes of such amplitude that at the peak amplitude of said waves, for a given half-cycle the resultant momentary decrease in the normal discharge current through one of said push-pull connected tubes reduces the discharge current through said tube near to zero.

37. In combination a pair of space discharge devices, each of said devices having a cathode, an anode and a grid or control element, anode circuits and grid circuits for said devices, a common source of discharge current connected to said anodes, a common source of alternating current potential connected to said grids, said devices being connected to operate in push-pull relation, the normal discharge current through said tubes being so related to the amplitude of the alternating potential impressed on said grids that at the peak amplitude of said alternating potential the space current through one and the other of said devices alternately is reduced substantially to zero.

38. In an electric system, an incoming circuit and a plural stage amplifier for amplifying signals from said circuit, said amplifier comprising at least one stage consisting of a single electron discharge tube and a stage consisting of a pair of electron discharge tubes connected in push-pull relation, having their input sides connected to the output side of said first mentioned stage, means for supplying discharge current to said tubes, the amplitude of the signal variations in the discharge current of said push-pull tubes being of the order of magnitude of the normal discharge current through said tubes.

In witness whereof, I hereunto subscribe my name this 31st day of August A. D., 1915.

HAROLD DE FOREST ARNOLD.

DISCLAIMER

1,504,537.—*Harold De Forest Arnold*, Maplewood, N. J. POWER-LIMITING AMPLIFYING DEVICE. Patent dated August 12, 1924. Disclaimer filed June 24, 1933, by the assignee, *American Telephone and Telegraph Company*.

Hereby enters this disclaimer to claims 17, 18, 20, 33, 34, 35, and 36 of said Letters Patent, to wit:

"17. An amplifier comprising two electrical discharge devices, input and output circuits therefor, said devices being symmetrically and oppositely disposed with respect to each of said circuits, space current paths for said devices, said paths having a common external portion of high impedance.

"18. An amplifier comprising two electrical discharge devices, input and output circuits therefor, said devices being symmetrically and oppositely arranged with respect to each of said circuits, space current paths for said devices, a source of space current therefor, said paths having a common external portion, and means associated with said source for preventing fluctuating currents therethrough."

"20. A repeater comprising two electric discharge devices each having a cathode an anode and an impedance varying element, a connection between said impedance varying elements, a connection between said cathodes, a connection between said anodes, an electrical impedance in one of said connections, an electrical impedance in another of said connections, other connections from intermediate portions of each of said impedances to one of said first mentioned connections, one of said last named connections being provided with a source of current, and means tending to maintain a constant supply from said source."

"33. In an electric system, an incoming circuit and a plural stage amplifier for amplifying signals from said circuit comprising in one stage of said amplifier two vacuum tube repeaters connected in push-pull relation, and at least one stage consisting of a single vacuum tube amplifier feeding into said push-pull stage.

"34. In the amplifying system in which the amplitude of the current increases in succeeding stages, a current responsive device actuated by the energy from said system, at least one preliminary amplifying stage consisting of a single vacuum tube amplifier circuit, and a succeeding stage for delivering the amplified current to said responsive device, said last mentioned stage comprising a pair of vacuum tube amplifiers connected in push-pull relation.

"35. In a plural stage amplifier circuit for amplifying signal currents, employing vacuum tube amplifiers in which, for relatively strong output currents at least, as the amplitude of the repeated wave becomes larger the distortion of the wave increases, said amplifier circuit comprising at least one stage consisting of a single vacuum tube repeater operating over a relatively small current amplitude range and giving amplification with the required degree of faithfulness of repetition of the signal and a stage into which said single tube stage feeds, for amplifying the repeated wave up to a current amplitude at which undesired distortion would take place in a single one of said tubes used alone, said later stage comprising a pair of vacuum tube repeaters connected in push-pull relation, whereby at said large current amplitude a faithfulness of repetition is obtained consistent with that of the preceding stage.

"36. In combination, three electron discharge tubes, means for supplying discharge current to said tubes, two of said tubes being connected in push-pull relation, the other one of said tubes being arranged to impress amplified signal waves on said push-pull connected tubes of such amplitude that at the peak amplitude of said waves, for a given half-cycle the resultant momentary decrease in the normal discharge current through one of said push-pull connected tubes reduces the discharge current through said tube near to zero."

[*Official Gazette July 18, 1933.*]

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June 11, 1929. E. H. ARMSTRONG 1,716,573

WAVE SIGNALING SYSTEM

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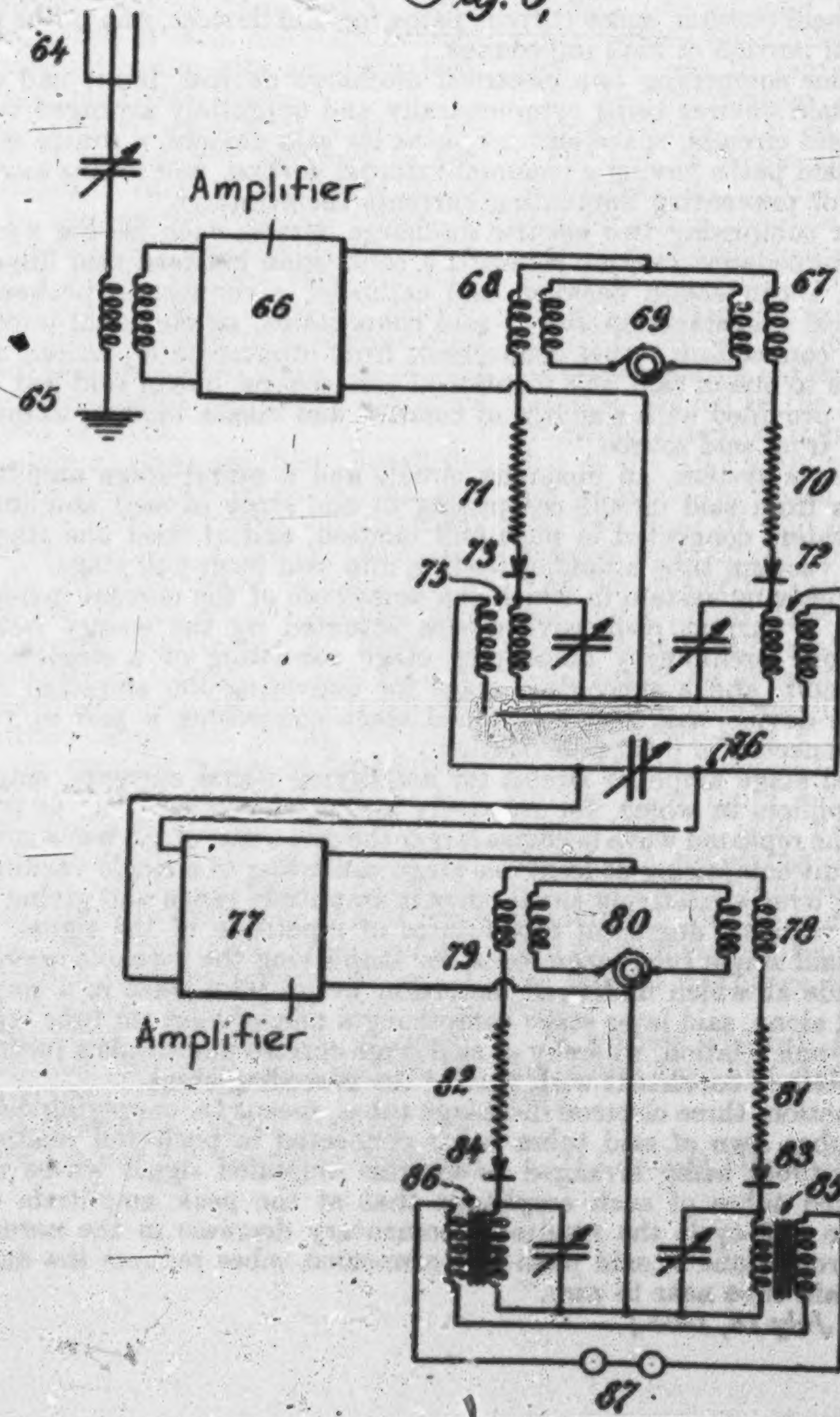
Fig. 6,



Inventor

Edwin H. Armstrong

By his Attorneys

Pennie, Davis, Marvin & Edmonds

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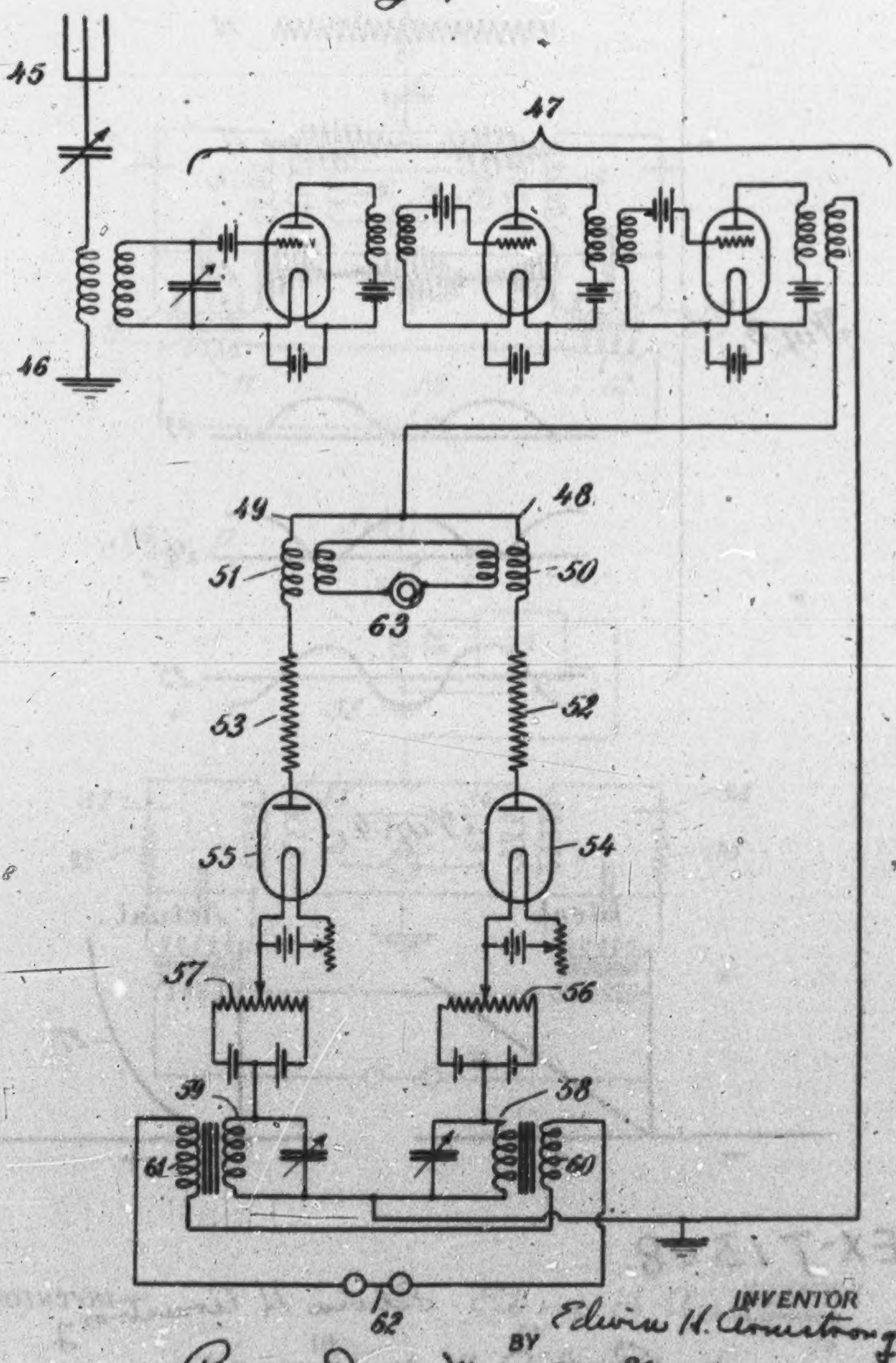
WAVE SIGNALING SYSTEM

Filed Feb 24 1922 4 Sheets-Sheet 3

Fig. 5,



INVENTOR
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WAVE SIGNALING SYSTEM
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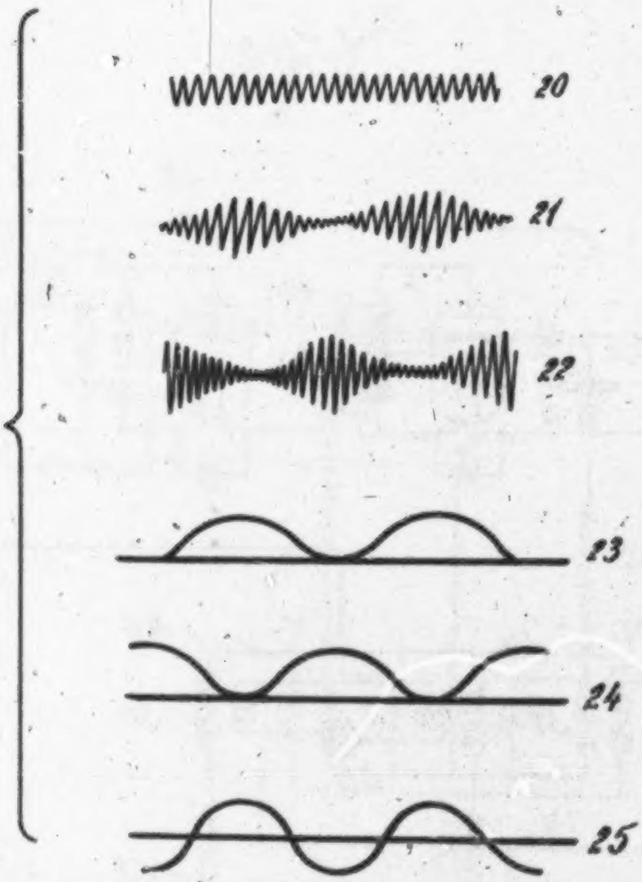
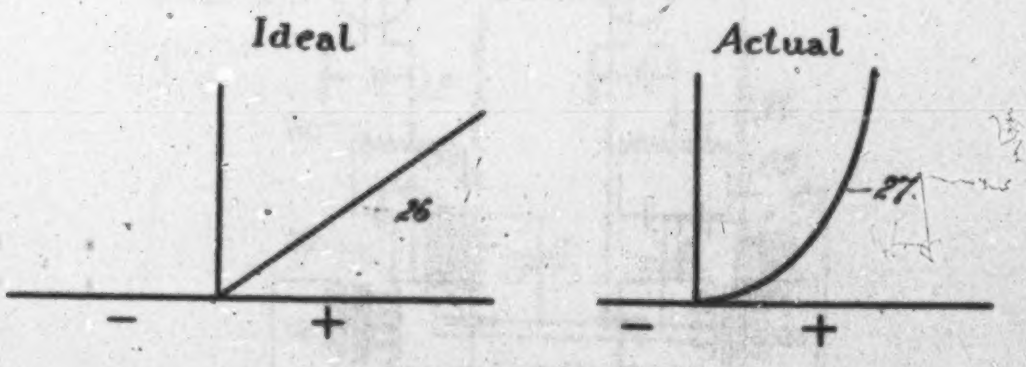


Fig. 3,

Fig. 4,



EX-T-1308

Edwin H. Armstrong INVENTOR
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June 11, 1929. E. H. ARMSTRONG 1,716,573

WAVE SIGNALING SYSTEM

Filed Feb. 24, 1922 4 Sheets-Sheet 1

Fig. 1,

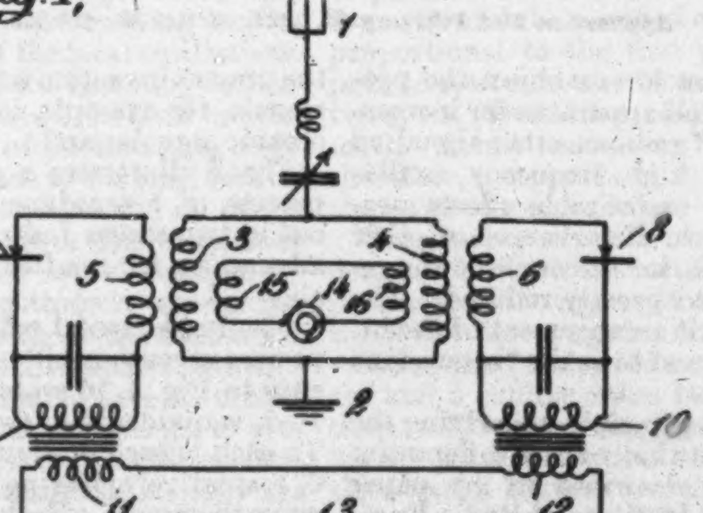
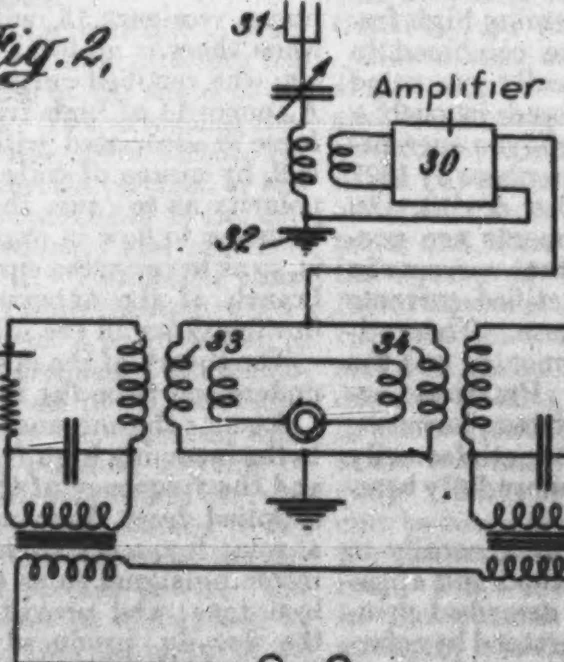


Fig. 2,



Edwin H. Armstrong INVENTOR

BY

Pennie, Davis, Marvin & Edmonds ATTORNEY'S

Patented June 11, 1929. 1,716,573

UNITED STATES PATENT OFFICE.

EDWIN H. ARMSTRONG, OF YONKERS, NEW YORK.

WAVE SIGNALING SYSTEM.

Application filed February 24, 1922. Serial No. 538,856.

This invention has for its object the provision of a method and apparatus for increasing the selectivity of radio or other signaling systems employing high frequency oscillations, whereby the undesirable effects produced by atmospheric disturbances or other types of interference, in the course of the reception of signals, are greatly reduced. The apparatus and circuit arrangement of the invention will be referred to as the "heterodyne balance".

The fundamental principle underlying the present invention is that of the differential heterodyne balance described in my paper delivered before the Institute of Radio Engineers, on March 5, 1915, published in vol. 3, No. 3, September 1915 of the "Proceedings of the Institute of Radio Engineers". In this paper a radio receiving system is illustrated and described wherein the incoming high frequency signal oscillations are combined in two separate circuits with locally generated high frequency oscillations, and in such a manner that the beat or heterodyne currents produced in one circuit differ in phase by 180° from that produced in the other circuit. In this system suitable arrangements are provided for rectifying the two beat currents in separate detectors and the rectified currents are combined in the proper phase. Theoretically the signal should be augmented and the disturbances balanced out. Practical arrangements employing this system, however, have not been found to operate satisfactorily for reasons which will appear more fully hereinafter.

The present invention relates generally to improvements both in the method and apparatus for utilizing the above described principle, and it will be better understood by reference to the following description and accompanying drawings. In these drawings:

Fig. 1 illustrates a system adapted to operate in accordance with the disclosure of the aforementioned radio institute paper;

Fig. 2 shows a simplified schematic circuit arrangement the mode of operation of which is in accordance with the present invention;

Fig. 3 illustrates schematically the character of the currents or oscillations which would theoretically exist in the various portions of the circuit arrangements of Fig. 1;

Fig. 4 shows ideal or straight line law and actual or normal square law characteristic curves of detectors;

Fig. 5 illustrates a practical application of the present invention to the reception of weak signals, for example, long distance or transoceanic signals; and

Fig. 6 illustrates a system in which the process of heterodyne balancing is carried out in two stages (cascade) whereby certain advantages hereinafter explained are obtainable.

The fundamental principle underlying the present invention will be understood by reference to Fig. 1, in which the antenna circuit 1—2, is divided into two equal branches 3, 4. To each branch is coupled secondaries 5 and 6, respectively, having detectors 7 and 8 in series therewith. Each detector also has connected in series therewith the primaries of telephone transformers 9 and 10 respectively. The secondaries 11 and 12 of these transformers are connected in series with the telephone receivers 13, with such polarity that when there is no local oscillation in the system, the rectified currents cancel each other. A source 14 of high frequency electromotive force is associated with the antenna circuit 1, 2, by means of coils 15 and 16, with such polarity as to cause the currents in the two branches to flow in opposite directions—that is, so as to cause the current to flow up in one branch of the antenna circuit, when it is flowing down in the other

The theory of the operation will be readily understood from the following analysis:

Assume the antenna circuit 1, 2 to be tuned to the incoming high frequency signal energy and the frequency of the electromotive force supplied from the source 14 to be adjusted at some frequency slightly different from the incoming signal so as to produce an audible beat tone; and providing the amplitude of the locally produced oscillations of the source 14 is adjusted to be equal to the amplitude of the incoming signal oscillations, the currents in the different portions of the circuit arrangement of Fig. 1 will be substantially as follows: (See Fig. 3).

In the antenna circuit 1, 2 the current is as illustrated by the graphic representation 20; the current in the branch 3, as at 21; the current in the branch 4 as shown at 22; while the rectified currents in the primaries 9 and 10 as shown at 23 and 24; the current in the telephones 13 may be represented as at 25.

It will therefore be understood that by combining the incoming signal oscillations with the local oscillations in the manner described, the phase of the rectified currents are shifted

180° with respect to each other and hence these two currents in the circuit containing the telephones, are in phase and reinforce each other.

It should be observed that the reversal of phase by the combination of the incoming and local oscillations, can be produced only when the amplitude of the incoming oscillations is less than that of the local oscillations. When the amplitude of the incoming oscillations is greater than that of the local oscillations, only components of the incoming oscillations equal in amplitude to the local oscillations can be reversed in phase and all of the incoming oscillations above this amplitude are accordingly cancelled out. Hence, on account of their great amplitude in comparison with both the signal and the local oscillations, oscillations produced by atmospheric disturbances or other types of interference are unable to combine with the local oscillations to produce beats. The interfering oscillations are, therefore, rectified substantially as they are and the two resulting rectified currents are then opposed in the circuit containing the telephones and cancel out with the exception of the component already mentioned, which is of negligible importance.

In the application of this principle to practice, a hitherto unsurmountable difficulty has been encountered because of the shape of all rectifier characteristics. The preceding theory assumes a straight line characteristic for the detector— that is, that the rectified or low frequency current is proportional to the amplitude of the high frequency electromotive force impressed upon it. The actual characteristics of detectors follow the square law; that is, the rectified current is proportional to the square of the high frequency electromotive force impressed upon it. This results in two difficulties; one is the increased difficulty of balancing the rectified currents or disturbances against each other since the relative magnitude of these disturbances in the secondaries 11 and 12 with respect to the signals are raised to the second power. The second difficulty may best be understood by reference to the graphic representation of the ideal and actual characteristic shown in Fig. 4 at 26 and 27 respectively.

First assume a signal having an amplitude proportional to one (1). Then assume that this signal is combined with a local oscillation which also has an amplitude proportional to one (1). The resultant beat current fluctuates in amplitude between two (2) and zero (0) in each of the branches 3 and 4 and therefore the amplitude of the signal in the circuit containing the telephone will be proportional to two (2).

Suppose now that a disturbing impulse arrives (for the most disturbing case) in phase with one branch of the antenna and 180° out of phase with the other branch of the antenna circuit. Assume also that the amplitude of the local oscillation is, as before, proportional to one (1) in each branch circuit; also suppose that the amplitude of the disturbance is proportional to five (5). The voltage impressed on the detectors 7 and 8 will vary in amplitude, therefore, between six (6) and four (4) and the rectified currents which are proportional to the first power of the impressed electromotive force vary similarly between six (6) and four (4). The net current in the circuit containing the telephones is, therefore, proportional to the difference of these two values, or to two (2).

Considering now the case of the practical detector in which the rectified current is proportional to the square of the impressed electromotive force; again, assume an arbitrary value of one (1) for the amplitude of the signal and a similar value for the local oscillations. The voltage impressed upon the detector by the combination of these two oscillations varies between a maximum of two (2) and zero (0) in each of the branches of the antenna circuit. The rectified current proportional to the square of these values varies between a maximum of four (4) and zero (0). The telephone current, therefore, is proportional to four (4).

Now assume an interfering impulse with an amplitude of five (5), the combined incoming and local energies producing an electromotive force which varies between a maximum of six (6) and a minimum of four (4). This electromotive force is impressed upon the detector and, since the rectified current varies as the square of the impressed electromotive force, produces a rectified current which varies between a maximum of thirty-six (36) and a minimum of sixteen (16) in one of the detector circuits, while the current in the other detector circuit is varying in the opposite sense between sixteen (16) and thirty-six (36). Hence the current in the telephone circuit becomes proportional to twenty (20) or five times the amplitude of the signaling current. Since the assumed initial disturbance in the antenna was five times the signal strength, it is apparent that no gain has been made in eliminating the disturbance.

In accordance with the present invention, the difficulties above described are overcome and the balancing operation carried out with the practical rectifier with the same degree of efficiency as could be obtained by the ideal rectifier. To this end a large resistance is inserted in series with each of the rectifiers. This straightens out and alters the characteristic of the rectifier after a certain initial electromotive force has been impressed thereupon and makes it approach the ideal rectifier. Secondly, the incoming signals are amplified sufficiently so that the initial bend in the rectifier characteristic is passed and rectification takes place on that part of the characteristic

curve which approximates the ideal. It will, therefore, be understood that the arrangement of Fig. 1 is modified in accordance with this invention to produce the arrangement illustrated in Fig. 2. It will be noted that the general arrangement is the same as in Fig. 1, except that an amplifier 30 of the high frequency waves is interposed between the antenna circuit, 31, 32 and the balanced circuits 33, 34; and two high resistances 35, 36 are inserted in series respectively with the rectifiers 37 and 38.

In the practical application of the method and apparatus of this invention to the reception of weak long distance signals, for example, transoceanic signals and the like, an arrangement such as that illustrated in Fig. 5 may be employed. It is advisable to use rectifiers of the valve type, preferably, the Fleming valve or two element vacuum tube. The resistance used in series with the rectifiers or detectors may be from one hundred thousand to two hundred thousand ohms. Extremely high amplification is necessary to produce an electromotive force of one or two volts across the detectors and resistances, and for this purpose six to ten stages of vacuum tube amplification may be necessary. It is also very important that the last stages of the amplifier should be composed of tubes capable of handling considerable power to prevent blocking or wiping out of the signal by disturbing impulses of large amplitude. On account of the extremely high amplification, it is advisable to shield all parts of the apparatus, particularly the generator of the local oscillations. It is also very important to keep the local oscillations from entering in or effecting the work of the amplifier, i. e., prevent reaction on the input of the amplifier otherwise the local oscillations will be amplified to such an extent by the amplifier that the last tubes thereof will be overloaded and will not function properly.

In Fig. 5 the antenna 45, 46 is coupled to a multi-stage amplifier 47, the number of stages depending on the initial strength of the signal. The two branch circuits 48, 49 each contain the coupling inductances 50, 51, respectively, the high resistances 52, 53 and the vacuum tube rectifiers 54, 55. Potentiometers 56 and 57 and telephone transformers 58 and 59 are also included in the two branch circuits respectively. The function of the potentiometer is to enable the adjustment of the rectifier characteristics of the two valves to be identical.

The operation of this system is substantially the same as that of Fig. 2. In this figure, however, all details required for the most perfect functioning of the system are illustrated. The incoming signals are received by the antenna system 45, 46, amplified to the required value by the amplifier 47 and then applied to the balanced circuits 48, 49. Here the currents are differentially combined with the local source 63, rectified by the valves 54, 55, the rectified currents being combined thru the transformer systems 58, 60 and 59, 61 and supplied to the telephones 62.

Where a single application of this principle is insufficient to overcome interference a cascade or multi-stage system as illustrated in Fig. 6 may be employed. This figure illustrates a double application of the heterodyne balance in which the incoming signals are reduced to audibility in two stages of the heterodyning with the balanced circuits applied in each stage. The various operations carried out will be understood from the following explanation: With this arrangement the incoming oscillations are received by antennæ 64, 65 and are then amplified by the amplifier 66. These amplified oscillations are then applied to the two branch circuits 67, 68 and differentially combined with a local source 69. The frequency of this source is adjusted to produce a beat frequency which is above good audibility. The combined currents are then rectified in accordance with the principles already explained by means of the rectifying systems 70, 72 and 71, 73 and the two rectified currents are then transferred by means of the transformers 74 and 75 to the circuit 76 where the signals are added cumulatively and the disturbances differentially. The resulting current which is of a lower frequency than the current in the antenna but a higher frequency than will give good audibility is then passed to an amplifier 77, amplified, and again applied to the balanced branch circuits 78, 79. In these circuits the currents are differentially combined with a local source 80 which is adjusted to give a beat frequency within the range of good audibility. The combined currents are then rectified by the rectifier systems 81, 83 and 82, 84, transferred to the telephone circuit by the transformers 85, 86, and combined in the telephones 87. It will be understood that the principle may be applied as many times as is desired. It will also be understood that the local current may be combined with the signaling current in only one of the branch circuits without departing from the spirit of the invention although the results will be inferior to making the combination in both branches.

As in the usual case, the antenna of the radio system may be replaced by conducting lines if it is desired to employ the invention in connection with carrier current systems.

What I claim is—

1. Apparatus for producing substantially unidirectional current from a source of alternating electromotive force comprising in combination, a rectifier having a nonlinear characteristic, a resistance connected to said rectifier for controlling the flow of current therethrough, and connections for impressing the electromotive force of said source

across said rectifier and resistance, the resistance being of such value with respect to the resistance of the rectifier as to cause the relationship of said rectified current with respect to said electromotive force to obey a substantially straight line law.

2. In combination, a rectifier having a nonlinear characteristic, a resistance serially connected to said rectifier so as to be traversed by the same current that flows through said rectifier, and means for impressing across said resistance and rectifier an alternating electromotive force, the value of said resistance and of said electromotive force with respect to the characteristic of said rectifier being such as to cause the rectified current to bear a substantially linear relationship with respect to said alternating electromotive force.

3. Means for producing from an applied alternating electromotive force a substantially unidirectional current substantially proportional to the first power of the said applied electromotive force comprising, in combination, a rectifier through which the current flows and which current is substantially proportional to the square of the difference of potential across the rectifier, and means having a different voltage-current characteristic connected to said rectifier for offsetting the nonlinear characteristic of the rectifier.

4. The method of improving the signal to disturbance ratio in a wave signaling receiving system which comprises causing the received energy to produce a plurality of alternating voltages; adding a locally supplied alternating voltage to one of said produced voltages while simultaneously subtracting a locally supplied alternating voltage, of the same frequency as said first mentioned locally supplied voltage, from another of said first mentioned produced voltages; separately producing rectified currents each proportional to the first power of a corresponding one of the combined voltages; converting the rectified currents into alternating currents; and combining the last mentioned currents.

5. The method of improving the signal to disturbance ratio in a wave signaling receiving system which comprises causing the received energy to produce a plurality of alternating voltages; adding a locally supplied alternating voltage to one of said produced voltages while simultaneously subtracting a locally supplied alternating voltage, of the same frequency as said first mentioned locally supplied voltage, from another of said first mentioned produced voltages; separately producing rectified currents each proportional to the first power of a corresponding one of the combined voltages; converting the rectified currents into alternating currents; combining the last mentioned currents; causing the combined current to produce a plurality of alternating voltages; and applying to the last mentioned produced alternating voltages the method above defined as applied to the first mentioned produced alternating voltages.

6. A wave signal receiving system comprising in combination, a branch circuit, means including a rectifier in said branch circuit for producing rectified current substantially proportional to the first power of the difference of potential across said branch circuit, a second branch circuit, means including a rectifier in said second mentioned branch circuit for producing rectified current substantially proportional to the first power of the difference of potential across said second mentioned branch circuit, means including a local source of oscillations for impressing alternating electromotive forces upon said branch circuits, a signal-indicating device, and means controlled by the rectified currents for operating said signal-indicating device.

7. A wave signal receiving system comprising in combination, a branch circuit, means including a rectifier in said branch circuit for producing rectified current substantially proportional to the first power of the difference of potential across said branch circuit, a second branch circuit, means including a rectifier in said second mentioned branch circuit for producing rectified current substantially proportional to the first power of the difference of potential across said second mentioned branch circuit, means for impressing locally generated oscillations upon the first mentioned branch circuit and for impressing locally generated oscillations upon the second mentioned branch circuit but substantially opposite in phase to the oscillations locally supplied to the first mentioned branch circuit, a signal-indicating device, and means controlled by the rectified currents for operating said signal-indicating device.

In testimony whereof I affix my signature.

EDWIN H. ARMSTRONG.

PATENT SPECIFICATION

Application Date: Aug. 31, 1920. No. 25,065/20. **172,376**

Complete Left: May 30, 1921.

Complete Accepted: Nov. 30, 1921.

PROVISIONAL SPECIFICATION.

Improvements in and relating to Radio Receiving Systems.

We, JOHN SCOTT-TAGGART, Electrical Engineer, a British subject, and RADIO COMMUNICATION COMPANY LIMITED, a company registered under the laws of Great Britain, both of 34–35, Norfolk Street, London, W.C. 2, do hereby declare the nature of this invention to be as follows:—

This invention relates to limiting and controlling oscillations in radio receiving systems. We propose to connect a conductor of unilateral or asymmetrical conductivity across a circuit in which received oscillations are taking place. When the said oscillations have a magnitude greater than a predetermined value, the said conductor acts as a damping device. A suitable device consists of a rectifier of unilateral conductivity such as a two-electrode thermionic valve. The valve is connected across the circuit in which the oscillations are produced, and a source of electromotive force is preferably connected so that the anode potential is negative. The valve will not conduct unless the oscillations have a magnitude greater than that of the said electromotive force which is preferably variable. We thus see that any oscillations of greater magnitude will be heavily damped while those of smaller magnitude will not be damped. If desired, two valves may be employed so as to damp both half oscillations. Other like arrangements are possible and may be used by employing the principles herein set forth. It may be desirable to connect a resistance in the oscillatory circuit or in the anode circuit of the valve. A three electrode valve may be used in a similar manner to a two electrode valve if the grid be given a suitable potential, preferably negative.

Other forms of rectifiers may be employed without departing from the scope of this invention and many other modifications, which will readily occur to those skilled in the art, may be made. Continuous waves may be received with an ordinary detector if the damping of the oscillations is made to take place periodically.

Dated the 30th day of August, 1920.

JOHN SCOTT-TAGGART.
RADIO COMMUNICATION COMPANY LIMITED.
The common seal of Radio Communication Co. Ltd. was hereto affixed in the presence of:
W. R. BROOKE,
T. W. STRATFORD-ANDREWS,
Directors.
E. B. SNOADES,
Secretary.

COMPLETE SPECIFICATION.

Improvements in and relating to Radio Receiving Systems.

We, JOHN SCOTT-TAGGART, Electrical Engineer, a British subject, and RADIO COMMUNICATION COMPANY LIMITED, a company registered under the laws of Great Britain, both of 34–35, Norfolk Street, London, W.C. 2, do hereby declare the nature of this invention and in what manner the same is to be performed, to

[*Price* 1/-]

be particularly described and ascertained in and by the following statement:—

This invention relates to signalling systems and particularly comprises means for limiting and controlling currents in a receiving circuit especially for lessening interference. The invention consists in part in providing a signalling receiving system comprising a source of input currents and a thermionic valve wherein currents through the valve are used to produce back electromotive forces for the purpose of lessening interference from sources external to the receiving station, for example outside transmitting stations or atmospherics. We prefer to use a rectifier which is non-conductive to weak currents but conducts when the currents are above a predetermined value. Further objects and novel features are disclosed in the description which follows and in the claims.

The invention in part consists in lessening interference by shunting a source of oscillating current, conveniently the closed receiving circuit, by a rectifier which is non-conductive to weak currents but conducts when the currents are above a predetermined amplitude. Since weak signals are unaffected, the invention possesses advantages over a previously proposed arrangement which employs a rectifier such as a Fleming valve shunted across a receiver and operating in such a way that weak signals produce a definite flow of current which flow, however, is greatly increased in the case of strong signals; in this previously proposed arrangement, the anode voltage of this Fleming valve is capable of variation between zero and a positive value; moreover, the invention as claimed specifies the use of two unidirectional conductors, whereas the present invention may involve only one.

To prevent any flow of current for weak signals we can arrange that a current is only produced when the applied circuits are sufficiently strong to overcome a force which tends to prevent a current flowing through the rectifier. The actual method we prefer to use is to connect a source of electromotive force somewhere in the anode circuit of the valve in such a way that the anode is normally negative and this negative potential should preferably be capable of variation. The current through a two-electrode valve commences to flow when the anode potential rises above approximately zero. Suppose now that the anode potential is - 2 volts; applied oscillations having an amplitude less than 2 volts will not cause the anode potential to rise above zero volts; consequently, no current will flow through the valve. If the amplitude of the oscillations exceeds two volts the positive half-cycles will cause the anode potential to rise above zero and current will flow.

We thus see that if a two-electrode valve be connected across, say, the closed receiving circuit of a wireless or other radio frequency system, limiting effects may be obtained. Weak signals will not be affected since no damping effect is produced. Strong signals, however, will be heavily damped as a current will flow through the valve.

Fig. 1 shows a wireless receiver working on this principle. A valve V_1 is connected across the circuit L_2 C_2, a battery B giving the anode of V_1 a negative potential. The second valve V_2 is acting as a detector of the oscillations in L_2 C_2. It must be understood that this form of detector is not essential nor is it necessary that the detector should be connected directly across the receiving circuit.

Two such rectifiers might be connected in opposition. Fig. 2 shows a circuit. The valves V_1 and V_3 are connected so as to conduct both half-cycles and so help to damp them out.

The detector may be connected across a circuit L_1 C_3 coupled to L_2 C_2.

Another method of connecting the valves is to arrange that the filaments are both connected to the middle point of the coil L_2 (Fig. 1). The two anodes are connected respectively to the two ends of L_2. Various other similar methods of producing full-wave conductivity may be used.

The limiting effects may be somewhat modified by including a resistance in the anode circuit of the two-electrode valve. Such a resistance may help to dissipate the current passed through the valve or may produce a back-electromotive force which will reduce the amplitude of the oscillations. Fig. 3 shows this arrangement. The inductance L_1 may be included in an aerial circuit. The resistance R which may have a value of about 1 megohm is connected so that when the strong positive half-cycle from L_2 C_1 is making the grid of V_2 positive the current through V_1 sets up an electromotive force across R which tends to make the grid of V_2 negative. In this manner strong oscillations have less effect on the grid V_2 than they otherwise would. In the anode circuit of V_2 is an oscillation circuit L_3 C_2 which may be connected to

a detector. The limitations of signals by the production of back electromotive forces obtained by Fig. 3 may be obtained in other ways but the method shown will serve as an example. The same principle may be used to limit audio frequency signals.

In this specification (including the claims) the word valve is used to indicate an electric discharge device, for example a thermionic tube, and is not limited to a rectifier.

Having now particularly described and ascertained the nature of our said invention, and in what manner the same is to be performed, we declare that what we claim is:—

1. A receiving signalling system comprising a source of varying current and a circuit shunted by a rectifier which is non-conductive to weak currents but conducts when the currents are above a predetermined amplitude.

2. A signalling receiving system comprising a source of varying current and a circuit associated with a rectifier which is normally non-conducting and which only conducts the varying currents when they are sufficiently strong to overcome a force which tends to prevent a current flowing through the rectifier.

3. A receiving signalling system particularly for radio signalling in which a two-electrode valve is shunted across a circuit in which varying potentials are established, a negative potential being applied to the anode of the valve.

4. In signalling systems the method of limiting currents in receiver apparatus which involves the use of a rectifier non-conductive to weak currents such as a two-electrode valve with a negative potential on its anode.

5. A wireless receiver in which a two-electrode valve acts as an absorber of current from an oscillatory circuit when the amplitude of the oscillatory current exceeds a predetermined value, a negative potential capable of variation being applied to the anode for the purpose described.

6. In wireless receiving apparatus the use of a rectifier such as a two-electrode valve with a negative potential on its anode in shunt to a circuit applying varying potentials, the current which flows through the rectifier when the varying potentials exceed a predetermined magnitude being used to lessen the effect of the original varying potentials.

7. A signalling receiving system comprising a source of input current and a rectifier such as a two-electrode valve which only becomes conductive when the input currents exceed a predetermined magnitude, the current through the rectifier being used to oppose the input currents.

8. A receiving system as in Claim 7 wherein the currents through the rectifier are passed through an impedance, preferably an ohmic resistance.

9. A signalling receiving system comprising a source of input currents and a valve wherein currents through the valve are used to produce back electromotive forces for the purpose of lessening interference from sources external to the receiving station.

10. A system as in Claim 9 in which the current through the valve is normally zero.

11. A system as in Claims 9 or 10 in which the back electromotive forces are only produced when the magnitude of the input currents exceeds a predetermined value.

12. A radio signalling system comprising a source of varying current applied to the grid and filament of a three-electrode valve, a two-electrode valve with a negative potential capable of variation on its anode shunted across said source, a resistance in the anode circuit of the two-electrode valve so arranged that when the two-electrode valve conducts, a back electromotive force is established in the resistance, the varying potentials applied to the grid of the three-electrode valve depending upon the negative potential of the anode of the two-electrode valve.

13. Apparatus as in any of the claims in which the varying currents are of radio frequency.

14. In any of the arrangements claimed the use of two two-electrode valves for the purpose of conducting both half-cycles substantially as described.

15. Apparatus as in any of the claims in which the varying currents are of audio frequency.

16. Apparatus substantially as described with reference to the figures.

Dated the 30th day of May, 1921.

JOHN SCOTT-TAGGART,
For the Applicants,
34/35, Norfolk Street, Strand, W.C. 2.

Redhill: Printed for His Majesty's Stationery Office, by Love & Malcomson Ltd.—1921.

[This Drawing is a reproduction of the Original on a reduced scale]

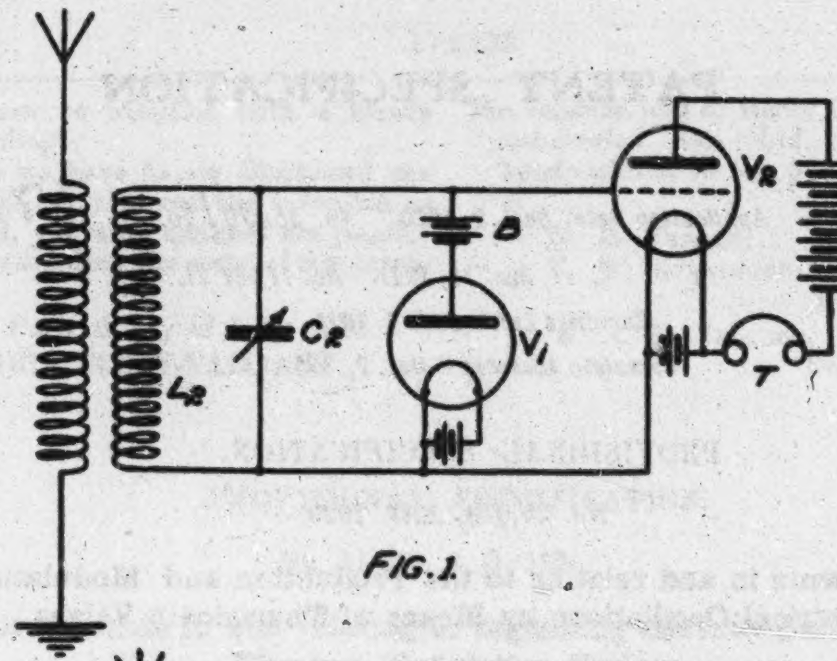


FIG. 1.

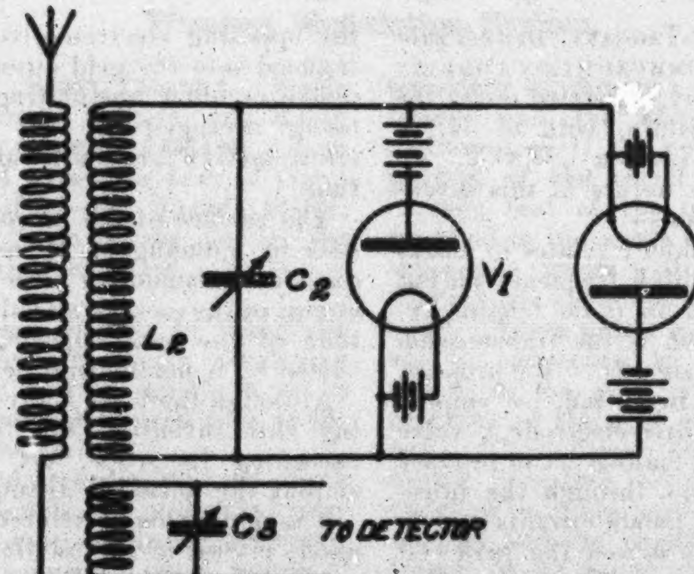


FIG. 2.

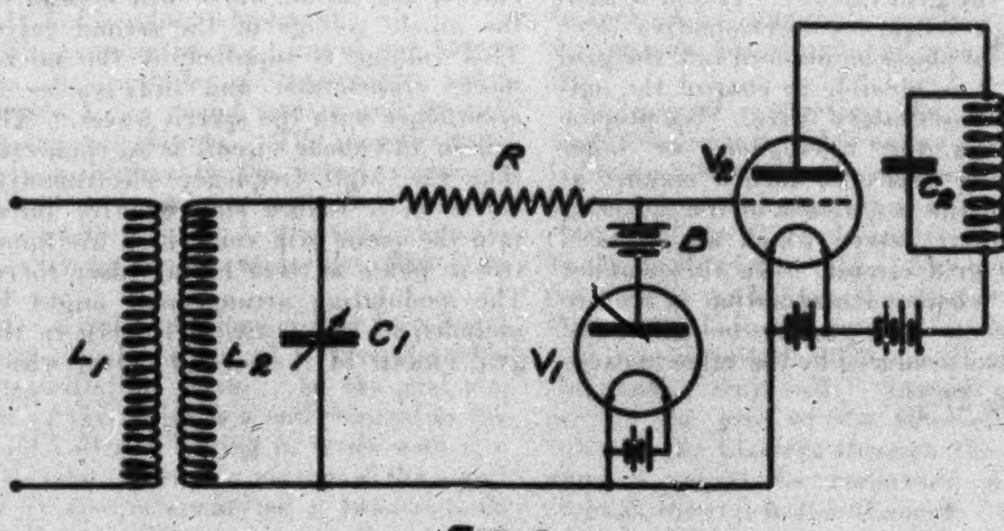


FIG. 3.

Malby & Sons, Photo-Litho

PATENT SPECIFICATION

Application Date: Sept. 2, 1920. No. 25,370/20.
" " Apr. 15, 1921. No. 11,061/21.
Complete Left: June 1, 1921.
Complete Accepted: Dec. 2, 1921.

172,389

PROVISIONAL SPECIFICATION.

No. 25,370, A.D. 1920.

Improvements in and relating to the Production and Modulation of Electrical Oscillations by Means of Thermionic Valves.

We, JOHN SCOTT-TAGGART, British subject, and RADIO COMMUNICATION COMPANY LIMITED, a company registered under the laws of Great Britain, both of 34/35, Norfolk Street, London, W.C. 2, do hereby declare the nature of this invention to be as follows:—

This invention chiefly relates to means of modulating the high frequency output of a valve as used in radio telegraphy. Its chief application is the transmission of radio telephone signals. We propose, according to this invention, to employ preferably a three-electrode valve arranged in such a manner as to produce electrical oscillations through the interaction of grid and anode circuits and to vary the potentials across the grid coil by coupling to it an oscillatory circuit in which are flowing oscillatory impulses opposite in phase to those taking place in the grid coil. It will be readily seen that the high frequency output of the oscillatory valve depends on the potentials in the grid circuit. If now a variable high frequency electromotive force of opposite phase be induced into the grid circuit, it is possible to control the output of the oscillatory valve. We propose to arrange the microphone or other modulating device in such a manner as to control the magnitude of the opposing electromotive forces which are induced into the grid circuit. In this manner wireless telephone modulation is readily obtainable. We propose to utilise the oscillations produced by the valve to cause the opposing electromotive forces to be induced into the grid circuit, the microphone or other modulating arrangement being arranged so that the opposing electromotive forces are varied in magnitude.

The essence of the invention thus consists in inducing an opposing high frequency electromotive force into the grid circuit of the oscillating valve, the magnitude of the said opposing force being varied by a modulating device.

Although there are many ways of carrying this invention into effect without exceeding its scope, yet we prefer to employ the following arrangement:

The oscillations produced in a grid or anode circuit of the oscillating valve are applied across the filament and grid of a second valve which acts as an amplifier. In the anode circuit of this valve is an inductance coil and the secondary of the microphone transformer. The oscillatory current in the coil in the anode circuit of the second valve will depend on the anode voltage of the second valve. This voltage is supplied by the microphone transformer and thus varies in accordance with the speech waves. The coil in the anode circuit is so connected that the high frequency electromotive forces in it induce electromotive forces into the main grid coil which are opposite in phase to those taking place there. The modulating arrangement might be included in series with a battery in the grid circuit of the second valve, which

[Price 1/-]

would now be supplied with a steady anode voltage.

While we have herein illustrated one method of carrying out the invention as described, yet other methods are possible without exceeding the scope of our invention.

Dated the 17th day of July, 1920.

JOHN SCOTT-TAGGART,

The common seal of Radio Communication Co. Ltd. was hereto affixed in the presence of

W. R. BROOKE,
T. W. STRATFORD-ANDREWS,
Directors,
E. A. B. SNOADEN,
Secretary.

PROVISIONAL SPECIFICATION.

No. 11,061, A.D. 1921.

Improvements in and relating to Signalling Systems particularly Wireless Modulation System.

We, JOHN SCOTT-TAGGART, Radio Engineer, a British subject, and RADIO COMMUNICATION COMPANY LIMITED, a company registered under the laws of Great Britain, both of ~~34~~—35, Norfolk Street, London, W.C. 2, do hereby declare the nature of this invention to be as follows:—

This invention relates to signalling systems, particularly those employing high-frequency current which is to be modulated or controlled according to the signals to be transmitted.

It is proposed according to part of the invention to employ a unilateral conductor such as a two-electrode thermionic valve and to connect it to a source of high-frequency potential in such a manner that the conductivity of the valve changes with the potential of a secondary source of current. It is proposed to employ the currents passing through the valve in a modulation system, particularly for wireless telephony.

We propose in one form of our invention to provide a thermionic valve coupled to an aerial system and providing current thereto. The magnitude of the oscillations in the aerial system is limited in accordance with the signals to be transmitted. A practical example of carrying our invention into effect is as follows:

An aerial oscillatory circuit forms part of the anode circuit of a three-electrode self-oscillating valve. In the grid circuit of this valve is a coil coupled to the aerial coil and having in series with it a resistance. Across a portion of the aerial inductance is connected a two-electrode valve in series, a source of potential arranged to make the anode negative, the secondary winding of a microphone transformer and the afore-mentioned grid resistance. If the potential across the portion of the aerial inductance used exceeds that of the negative potential supplied to the anode of the valve high-frequency pulses will be communicated through the valve and through the resistance. These pulses may be arranged to act in opposition to the simultaneous pulses in the grid circuit due to the coupling of the grid coil and the aerial coil. The ordinary high-frequency grid circuit potentials obtained by magnetic coupling with the aerial coil will now be reduced and the amplitude of the oscillations in the aerial circuit will also be correspondingly reduced until a balance is obtained. It will be clearly seen that the high-frequency output of the three-electrode valve will depend upon the negative potential on the anode of the two-electrode valve. This potential may be altered by potentials supplied by the microphone transformer as when speaking.

Instead of connecting the resistance and two-electrode valve across the aerial inductance they may be connected across a coil coupled to one of the oscillatory circuits of the three-electrode valve such as the anode circuit coil. The action in this case is as before, the magnitude of the potentials in the coupled coil varying with the magnitude of the oscillations in the anode circuit coil. Instead of connecting the grid of the three-electrode valve to the filament through the resistance it might be connected directly through the coil to the filament. In this case the resistance and two-electrode valve would be connected as before, but the

potentials across the resistance might be applied to a second grid acting in opposition to the first.

The examples we have herein described are merely for the purpose of illustration as the applications of phase opposition devices of this kind to modulation systems are too numerous to describe here. For example, while we have shown the invention applicable to self-oscillating valves in which self-oscillations may be produced in any desired manner yet the invention is also applicable to separately excited amplifier systems in which a local source of oscillations is applied to the grid of a three-electrode valve whose output circuit is connected to an aerial or line; in this case the circuital arrangements operate as in the examples. The grid coil, however, is not coupled to the anode circuit coil, but is coupled to a local source of continuous oscillation. Although unilateral conductors such as rectifiers are preferred yet a three-electrode valve might be used, the modulating potentials being applied to the grid.

Although we have described the use of a resistance yet an impedance or inductance, or their equivalents may be used.

Dated this 15th day of April, 1921.

JOHN SCOTT-TAGGART,

The common seal of Radio Communication Company Ltd., was hereto affixed in the presence of:

J. Herbert Tomkin,
T. W. Stratford-Andrews,
Directors,
E. A. B. Snoaden,
Secretary.

COMPLETE SPECIFICATION.

Improvements in and relating to Signalling Systems particularly Wireless Modulation System.

We, John Scott-Taggart, Radio Engineer, a British subject, and Radio Communication Company Limited, a company registered under the laws of Great Britain, both of 34—35, Norfolk Street, London, W.C. 2, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to transmitting signalling systems in which an amplifier is used having means for producing in the input circuit of the amplifier controllable electromotive forces which act in opposition to the electromotive forces to be amplified. The invention particularly provides a wireless telephone transmitter and modulation may be obtained in either a self-oscillatory valve circuit or one in which the grid circuit of a power amplifier valve is separately excited by a source of oscillations. We prefer to use an ordinary three-electrode valve as an amplifier and a two-electrode or three-electrode valve as a means of controlling the grid potentials of the main amplifier. We prefer to arrange that the back electromotive forces are only applied to the grid circuit of the amplifier when the currents applied to the controlling valve exceed a predetermined amplitude.

In a self-oscillating system we derive the electromotive forces (which are ultimately reintroduced into the grid circuit of the amplifier with or without amplification) either inductively (by "loop coupling") from the grid circuit or in any manner from the anode circuit of the amplifier. We do not desire to connect a rectifier in shunt to the grid circuit of an amplifier as has been proposed in a prior Application (169,250 of June 19, 1920) in which the Radio Communication Company Limited was an applicant.

In a separately excited arrangement we use a separate source of continuous oscillations, such as an oscillating valve, to influence the grid of a three-electrode valve amplifier, the output circuit of which is associated for example with an aerial system. We now derive our electromotive forces from the original separate source, the input side or the output side of the amplifier, or otherwise.

If we apply these electromotive forces to a rectifier we prefer to use a two-electrode valve having a negative potential on its anode. We may however amplify our electromotive forces by applying them to the grid of an ampli-

fying three-electrode valve, in which case the grid is given a steady negative potential at least sufficient to cut down the anode current of the same valve to substantially zero.

In a wireless telephone transmitter we apply the microphone potentials to the rectifier or when a three-electrode valve is used to amplify the opposing electromotive forces, to the grid of the said valve.

Various means of passing the opposing electromotive forces into the input side of the amplifier may be adopted but we have found that by including a resistance in the grid circuit of the amplifier and passing the varying opposing currents through this resistance, the desired back electromotive forces are produced across the resistance. In this way the potentials applied to the grid will depend upon the difference between the main input and the opposing potentials. The output of the amplifier will thus vary with the microphone potentials.

The invention will best be understood by reference to the drawings which, however, are only examples of the various ways in which the invention may be carried out.

Fig. 1 shows a self oscillating valve V_1 with an output circuit L_2. A grid coil L_1 is connected across grid and filament of the valve V_1. This coil is coupled to the coil L_2 to produce self-oscillation. A second coil L_3 is connected in series with a high resistance R (a resistance of 100,000 ohms has given good results) and a two electrode valve V_2, the anode of which is given a negative potential by means of a battery B. The coil L_3 is coupled to either L_1 or L_2 in such a manner that when high-frequency impulses pass through V_2 they set up electromotive forces across R which give the grid potentials of opposite sign to those produced by the coil L_1. The magnitude of the opposing electromotive forces is varied by the microphone M which through the intermediary of the transformer T varies the anode potential of V_2. When the anode of V_2 is highly negative, no impulses are passed through V_2. When, however, the positive half-cycles of the microphonic current lessen the negative potential on the anode of V_2, currents are passed which have a value approximately proportional to the microphonic potentials. Other parts of the circuits will be readily understood by reference to the drawing.

Fig. 2 shows a power amplifier V_1 having a grid coil L_1 coupled to a source of oscillations, such as a valve oscillator. As before a resistance R, a valve V_2 and a coil L_3 form the opposing electromotive force circuit. The coil L_3 may be coupled to L_2, the coil L_1 or the coil L_4. The opposing electromotive force may be obtained from any part of the circuits in any way except directly from the grid circuit. The arrangement of Fig. 2 operates in the same manner as Fig. 1, varying opposing electromotive forces being applied to the grid of the valve.

Apart from these forms of our invention it is proposed to produce the back-electromotive forces by applying radio frequency currents derived from the input or output sides of an amplifier to the input side of a second amplifier, the controlling means of said second amplifier being arranged to reduce the anode current to substantially zero. The anode radio frequency currents produced when the controlling means of the second amplifier are influenced for example by microphone currents are made to act back on the input side of the first amplifier. We prefer to use two ordinary three-electrode valves one of which acts as the main source of oscillations and the second one as a modulator. The oscillations in the grid circuit of the first are applied to the grid and cathode of the second, the anode circuit of the second, including an impedance, preferably a resistance, which is also included in the grid circuit of the first valve. The steady grid potential of the second valve is more than sufficiently negative to keep the anode current of the second valve down to zero; a microphone is caused to vary this normal negative potential. When speaking, the negative potential is lessened by the positive half-cycles of microphone current; the amplified radio frequency output is increased and this output current passing through the resistance produces back electromotive forces in the grid circuit of the first valve. The magnitude of the back-electromotive forces (and therefore the output of the first valve) will vary with the microphone potentials on the grid of the second valve.

Fig. 3 shows a self-oscillating valve system in which V_2 represents the second valve and B_1 the battery which gives the grid of V_2 a high negative potential. The battery B_2 provides the anode voltage for V_2. The battery B_3 keeps the grid of V_1 suitably negative. The operation of this circuit which oscillates of its own accord by coupling L_1 to L_2 has already

been described. The arrangement of Fig. 4 corresponds to Fig. 3, except that the valve V_1 acts only as a power amplifier, a separate source of oscillations exciting its input side. Various modifications of these two circuits may be devised without exceeding the scope of the invention.

Having now particularly described and ascertained the nature of our said invention, and in what manner the same is to be performed; we declare that what we claim is:—

1. A transmitting signalling system in which an amplifier is used having means for producing in the input circuit of the amplifier controllable electromotive forces which act in opposition to the electromotive forces to be amplified, the opposing electromotive forces being obtained by magnetic coupling with the input circuit of the amplifier and reintroduced by means of a resistance or otherwise into the input circuit of the amplifier.

2. A transmitting signalling system comprising an amplifier having input and output sides in which current variations are derived in any manner from the output side of the amplifier and reintroduced in a reverse direction into the input side.

3. A transmitting signalling system according to Claims 1 or 2 in which the back electromotive forces are produced in the anode-cathode circuit of an electric discharge device and reintroduced into the control circuit of the amplifier which consists of a second electric discharge device.

4. A transmitting system according to Claims 1, 2 or 3 in which the electromotive forces to be reintroduced into the control circuit of the amplifier are applied to a rectifier.

5. A system as in Claim 4 in which the rectifier takes the form of a two-electrode valve with a negative potential on its anode.

6. A signalling system employing an amplifier of radio frequency currents in which electromotive forces similar to those to be amplified are applied to the control side of an electric discharge device the output side of which is coupled or connected to the input side of the amplifier for the purpose of producing back electromotive forces in that circuit, the current through the said electric discharge device being normally substantially zero (due to the action of its controlling means) when the electromotive forces are not applied.

7. A signalling system according to Claim 6 in which the electromotive forces to be reintroduced are applied to the grid of a three-electrode valve, the steady grid potential of which is at least sufficient to cut the anode current of the valve down to zero.

8. A signalling system as in any of the preceding claims in which the amplifier takes the form of an ordinary three-electrode valve.

9. A wireless transmitting signalling system according to any of the preceding claims in which radio frequency currents are modulated by varying the magnitude of the back electromotive forces.

10. A modulation radio frequency transmitter in which a three-electrode valve is caused to generate oscillations of its own accord, radio frequency currents being derived inductively from the grid circuit or in any manner from the anode circuit and applied to a two-electrode valve the anode circuit of which includes a source of steady electromotive force which makes the anode normally negative, a microphone transformer or other source of modulating currents and a high resistance, the latter forming part of the grid circuit of the first valve.

11. A modulation radio frequency transmitter comprising a separately excited three-electrode valve amplifier in which radio frequency currents similar to those applied to the grid circuit of the amplifier are applied to a two-electrode valve having a negative potential on its anode (or other suitable rectifier), the current through the two-electrode valve being utilised to produce back electromotive force in the grid circuit of the amplifier, preferably by passing them through a resistance in the grid circuit of the amplifier.

12. A modulation radio frequency transmitter in which a three-electrode valve is caused to generate oscillations of its own accord, radio frequency currents being derived in any manner from the grid circuit or in any manner from the anode circuit and applied to the grid of a second three-electrode valve (the grid potential of which is at a normal steady negative potential sufficient to reduce the anode current to substantially zero) the anode circuit of which includes a steady source of electromotive force and a resistance included in the grid circuit of the first valve, modulation being accomplished by varying the potential of the grid of the second valve.

13. A modification of the arrangement

of Claim 12 in which the first valve is not self-oscillatory but has its grid circuit excited by a separate source of continuous oscillations.

14. Signalling systems according to any of the claims in which the back-electromotive forces are only reintroduced into the control circuit of the amplifier when they exceed a predetermined amplitude.

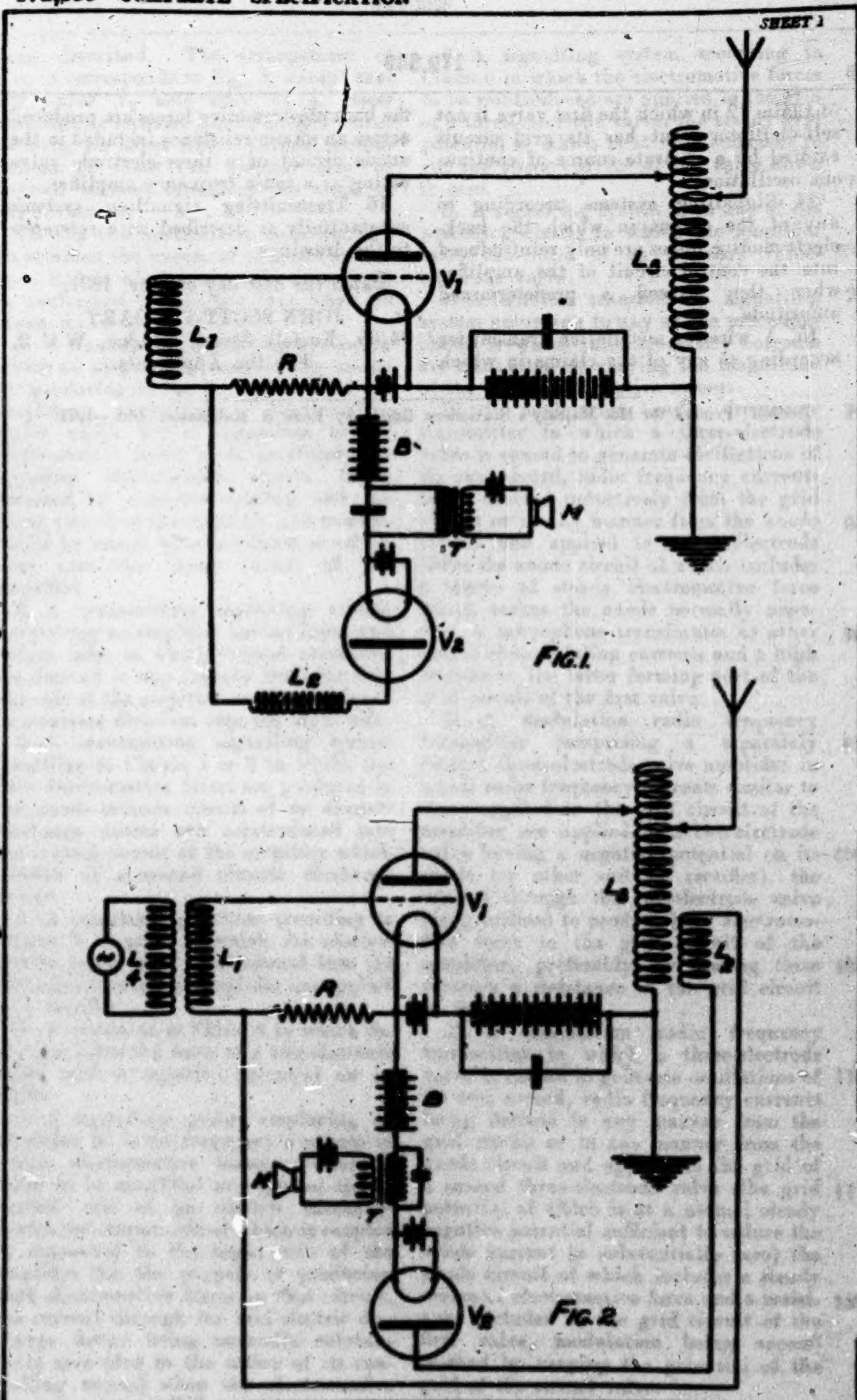
15. A wireless modulation transmitter according to any of the claims in which the back electromotive forces are produced across an ohmic resistance included in the anode circuit of a three-electrode valve acting as a radio frequency amplifier.

16. Transmitting signalling systems substantially as described with reference to the drawings.

Dated the 31st day of May, 1921.

JOHN SCOTT-TAGGART,
34/35, Norfolk Street, London, W.C. 2,
For the Applicants.

Redhill: Printed for His Majesty's Stationery Office, by Love & Malcomson, Ltd.—1921.



[This Drawing is a reproduction of the Original on a reduced scale]

PATENT SPECIFICATION

Application Date: Aug. 30, 1921. No. 23,013/21.

Complete Left: June 30. 1922.

Complete Accepted: Feb. 28, 1923.

193,882

PROVISIONAL SPECIFICATION.

Improvements in and relating to Signalling Systems Employing Electric Oscillations.

We, JOHN SCOTT-TAGGART, Electrical Engineer, a British subject and RADIO COMMUNICATION COMPANY LIMITED, a company registered under the laws of Great Britain, both of 34/35, Norfolk Street, London, W.C. 2, do hereby declare the nature of this invention to be as follows:—

This invention relates to improvements in signalling systems particularly wireless receiving systems. It is proposed to employ continuous waves for the transmission of intelligence.

It is proposed according to this invention to modify the effect of incoming signals so as to render them capable of actuating an indicator such as a telephone receiver to the best advantage.

One arrangement is to apply the incoming signals to the anode and cathode of a thermionic valve and to apply to the control means (for example, a grid), a high-frequency current of a frequency slightly different from the incoming frequency, which will produce an audible indication in telephone receivers connected in the anode circuit.

It is also proposed to rectify the incoming signals and apply to the unidirectional impulses other impulses, preferably unidirectional but not necessarily so, of slightly different frequency. The resultant currents may now be applied to the indicator.

We also propose to receive continuous waves by arranging local oscillations or impulses which are not constantly operative but which only come into action when signals are received. The local oscillations are made to form beats with the incoming signals which are then detected. The continuous oscillations might for example, be applied to the grid of a valve in the anode circuit of which is a resistance. Across this resistance is connected the grid and filament of a second valve, a source of oscillations differing slightly in frequency from the incoming signals and a battery being included in the grid circuit. In the anode circuit of the second valve is a coil which may be arranged so to induce into the aerial or other suitable circuit. When no signals are arriving, the grid of the second valve is sufficiently negative to prevent the local source from producing any output current in the coil. The local source, however, will be made operative when signals arrive, since the signals will lessen the negative potential on the grid and produce a high-frequency current in the coil which will form beats with the incoming signals. By adjusting the grid potential it is possible to differentiate between different signals. Weak signals, for example, might not make operative the local oscillations and no beats would be produced. We desire to cover all methods of beat reception which use a discontinuous source of local oscillations, including both mechanical and electrical methods. Two aerial systems may be used. One to receive the signals to be detected and the other to receive the signals which set into action the local oscillations.

Special effects may be obtained with our invention. If desired it may be arranged that different signals alter the frequency of the local oscillations. For example, very strong signals might be made to alter the frequency of the local oscillations sufficiently to prevent the formation of audible beats. Strong signals might thus be arranged to give no effect in the receiver.

Another means for differentiating between different signals consists in applying different signals (for example spark and continuous wave signals) to a

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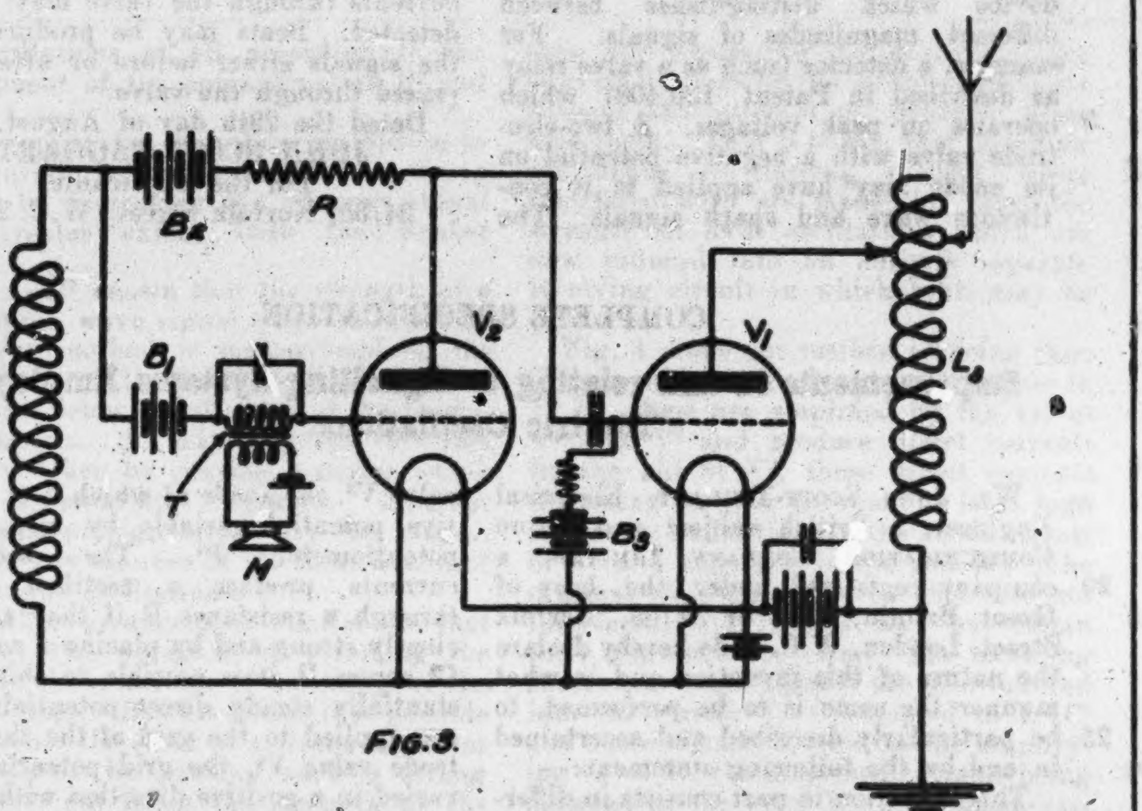

FIG. 3.

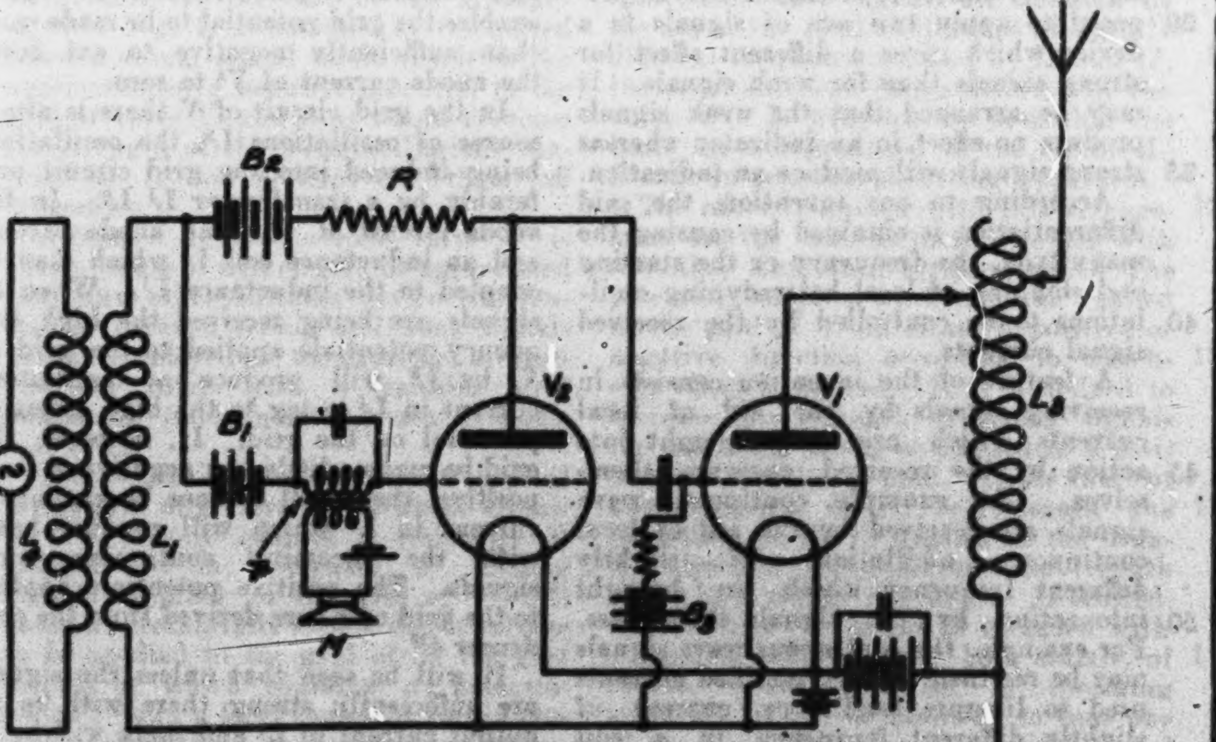

FIG. 4.

device which distinguishes between different magnitudes of signals. For example, a detector (such as a valve relay as described in Patent 130,408) which operates on peak voltages. A two-electrode valve with a negative potential on its anode may have applied to it continuous wave and spark signals. The currents through the valve may be then detected. Beats may be produced with the signals either before or after being passed through the valve.

Dated the 29th day of August, 1921.

JOHN SCOTT-TAGGART,
For the Applicants,
34/35, Norfolk Street, W.C. 2.

COMPLETE SPECIFICATION.

Improvements in and relating to Signalling Systems Employing Electric Oscillations.

We, JOHN SCOTT-TAGGART, Electrical Engineer, a British subject and RADIO COMMUNICATION COMPANY LIMITED, a company registered under the laws of Great Britain, both of 34/35, Norfolk Street, London, W.C. 2, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention in part consists in differentiating signals, particularly wireless signals of different strength. It is proposed to apply two sets of signals to a device which gives a different effect for strong signals than for weak signals. It may be arranged that the weak signals produce no effect in an indicator whereas strong signals will produce an indication.

According to our invention, the said differentiation is obtained by causing the magnitude, the frequency or the starting and stopping of local heterodyning oscillations to be controlled by the received signal currents.

A feature of the invention consists in receiving signals by the aid of local currents which are only brought into action by the received currents themselves. For example, continuous wave signals are received by the aid of local continuous oscillations of slightly different frequency which are brought into action by the signals themselves. For example, the continuous wave signals may be rectified and the rectified currents used to liberate oscillatory current of slightly different frequency in a coil which may be coupled to the original main receiving circuit. One effect of such a device is that continuous wave signals control the actual means by which they are received.

Fig. 1 of the accompanying drawings shows an arrangement which may be used. The incoming oscillations in L^1 C^1 are amplified by two valves V^1 and V^2, the amplified currents appearing in L^2. They are now applied to a two-electrode valve V^3, the anode of which is at a negative potential variable by means of a potentiometer P^1. The oscillatory currents produce a rectified current through a resistance R if they are sufficiently strong and by placing a condenser C^3 across R it is possible to obtain substantially steady direct potentials which are applied to the grid of the three-electrode valve V^4, the grid potential being varied in a positive direction with respect to the filament of V^4. The grid circuit also contains a potentiometer P^2 which enables the grid potential to be made more than sufficiently negative to cut down the anode current of V^4 to zero.

In the grid circuit of V there is also a source of oscillations L^3, the oscillations being induced into the grid circuit preferably by a transformer L^3 L^5. In the anode circuit of V^4 is an anode battery and an inductance coil L^6 which may be coupled to the inductance L^1. When no signals are being received the high frequency potentials applied to the grid of V^4 by L^3 will produce no oscillatory current in L^6 owing to the high negative potential on the grid. If, however, the grid be made a little less negative or even positive, there will at once be an output current in L^6 which will produce beats with the incoming continuous wave signals. The positive potentials applied to the grid of V^4 are derived from the condenser C^3.

It will be seen that unless the signals are sufficiently strong there will be no output current in L^6 and there will be no beats. Weak continuous wave signals would, therefore, produce no effect in the indicator which may take the form of telephone receivers T, connected in the anode circuit of the valve V^4.

This arrangement may be used for differentiating between different kinds of signals in various ways. Strong signals, for example, will produce stronger local oscillations whereas weak signals will either produce weak local oscillations or

no oscillations at all according to the adjustment of the potentiometers P^1 and P^2.

This apparatus, therefore, enables us to differentiate between a weak and a strong signal by increasing the stronger signal to a greater extent than the weaker signal.

It is well known that the strength of a continuous wave signal when received by the beat method is proportional to the magnitude of the local oscillations when these are below the strength of the incoming signals. An advantage of this fact may be taken by causing a device which will differentiate between different strengths of signals to vary the magnitude in any manner of the local source of continuous oscillations.

Another arrangement similar to that of Fig. 1 is obtained by reversing the leads to the condenser C^2 as shown by the dotted lines. By this means it is possible to decrease the effect of a strong signal or atmospheric by causing such a strong signal to cut down the strength of the local oscillations and perhaps cut them off altogether. In the case of the arrangement of Fig. 1, as modified by the dotted lines, a strong signal would result in the application of a negative potential to the grid of valve V^4 and thus would decrease the strength of the local oscillations supplied by L^4 and perhaps cut them off altogether.

Although a two-electrode valve V^3 is shown in use it will clearly be appreciated that any other suitable device differentiating between strong and weak signals may be employed as, for example, a three-electrode valve with a variable grid potential. Such an arrangement is shown in Fig. 2.

The oscillations in L^2 are now applied to the grid of a valve V^3 the anode circuit of which may contain a resistance R shunted by a condenser C^2. Strong signals applied to the grid of V^3 will cause a substantially steady direct voltage to be applied to the grid of V^4 the grid circuit of which contains a potentiometer P^2 and a local source of continuous oscillations L^3 as in the previous figure. The anode circuit of V^4 contains the coupling coil L^4 which is preferably coupled to L^1. It is to be understood that in all these cases the strength of the local source may be varied in any manner whatsoever and that the arrangements described and which employ a variable conductor are merely examples of how the desired result may be accomplished.

A modification of the arrangement described consists in applying the local oscillations to a separate circuit or circuits and regulating the strength of the local oscillations by the incoming currents without any attempt to produce beats with them. That is to say, that incoming continuous oscillations without being interfered with are made to vary the strength of local oscillations which are now induced into an entirely separate receiving circuit in which beats may be produced.

Fig. 3 shows one method of doing this. The incoming signals set up currents in L^1 C^1, these are amplified by the valves V^1 and V^2 and produce direct currents by the aid of V^3, these direct currents liberating varying amounts of local high frequency oscillations in the anode circuit of V^4 and therefore in the coil L^4. The original oscillations are in this case not interfered with in any way but retain their original wave form. The incoming continuous wave signals are also induced into the circuit L^5 C^5 coupled to L^1 C^1 and these signals are led to the amplifying valve V^5, the amplified currents being detected by the valve V^6 in the anode circuit of which are the telephones T. The continuous wave signals are detected by the aid of the local oscillations of slightly different frequency induced by L^6 and L^7, the resultant beats being detected by the valve V^6. It will thus be seen that the beats are not produced in the circuit L^1 C^1 but in separate detecting apparatus.

The effects obtained with this arrangement are the same as those obtained with the other mentioned arrangements. The potentials supplied by C^2 may be applied to the grid of V^4 in either a positive or negative direction according to whichever effect is desired. If it is desired to increase the strength of strong signals the potentials would be applied in a positive direction to the grid. If the effect of strong signals is to be lessened the potentials should be applied in the negative direction so as to decrease the strength of the local oscillations in L^4. If desired, the circuit C^5 L^5 might be included with a separate aerial system, both aerials, of course, being receptive to incoming signals. It may be desirable to tune one of the aerial circuits to the desired signal and the other aerial to interfering signals or otherwise to vary the receptivity of the two aerials.

Another feature of the invention is the variations of the local frequency by the incoming signals, for example, strong signals might be arranged to vary the frequency of the local oscillator and thus produce a different note in the receiver from that obtained with weak signals.

Fig. 4 shows an arrangement embodying this feature of the invention. In

this case we have two amplifying valves V^1 and V^2 and arrangement V^3 acting as a means of differentiating between different strengths of signals in the manner described, a valve V^4 acting as a variable conductor in shunt with an oscillating circuit L^{10} C^{30} associated with a valve oscillator V^5. The oscillatory circuit L^{10} C^{30} is coupled to the grid coil L^{11} and the valve V^5 generates continuous oscillations for the purpose of producing beats with the incoming continuous wave signals. The valve V^2 produces rectified currents through R and unidirectional potentials are applied to the grid of V^4 and vary its conductivity. This is equivalent to placing a variable resistance across the coil L^{10} and as a result the frequency of the oscillations in L^{10} C^{30} is varied. The coil L^4 is connected in the oscillatory circuit and serves as a means of inducing the local oscillations in the receiving circuits.

It will be seen that a very strong signal will change the frequency of the local oscillations considerably and may even vary the beat frequency in the telephones T to such an extent that it is outside the audible range, in which case a strong signal would produce no audible effect on the signals.

Fig. 5 shows the application of the principle to a separate detector circuit in a manner analogous to that shown in Fig. 3. The coil L^4 is now coupled to the inductance L^7 of a separate receiving circuit associated with the aerial circuit. If signals of different intensity are received different notes will be heard in the telephone receivers owing to the change of the frequency of the local oscillations.

The above arrangements are merely given by way of example and it will readily be seen that many variations are possible without exceeding the scope of the invention. The various arrangements may be combined with each other or with any other receiving apparatus and equivalent devices may be inserted in different parts of the circuits.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. A system for receiving continuous wave signals in which a local source of continuous oscillations interacts with the received currents the magnitude of the interacting local currents being controlled by the received currents.

2. A system for receiving continuous wave signals in which a local source of continuous oscillations interacts with the received currents, the magnitude of the interacting local currents being controlled by the magnitude of the received currents.

3. A system for receiving continuous wave signals other than that specifically claimed in Patent 181,799, in which a local source of continuous oscillations interacts with the received currents the frequency of the local currents being controlled by the received currents.

4. A system for receiving continuous wave signals, other than that specifically claimed in Patent 181,799, in which a local source of continuous oscillations interacts with the received currents, the frequency of the local currents being controlled by the magnitude of the received currents.

5. The method of receiving high frequency oscillations with a minimum of interference which consists in causing incoming current to control the magnitude of local heterodyning oscillations, the local oscillations being normally effected but being weakened or cut off by currents of a magnitude greater than a predetermined value.

6. Apparatus according to the previous claim in which, however, the stronger currents increase the strength of the local oscillations.

7. Apparatus according to Claim 5 in which the currents changing the amplitude or frequency of the local oscillations affect a separate receiving apparatus.

8. Apparatus according to any of the claims in which the differentiating apparatus comprises a variable conductor such as a two-electrode valve with a negative potential on the anode or a three-electrode valve with a negative potential on the grid substantially as described.

9. Wireless receiving apparatus according to any of the claims in which interference due to atmospherics, damped wave signals or signals of undesired character or amplitude, is lessened.

10. A continuous wave wireless receiving system in which the heterodyning oscillations derived from a local source are not constantly operative but are only effective when signals are received.

11. Apparatus substantially as described or illustrated.

Dated the 29th day of August, 1921.

JOHN SCOTT-TAGGART,
34, Norfolk Street, London, W.C. 2.
For the Applicants.

Redhill: Printed for His Majesty's Stationery Office, by Love & Malcomson, Ltd.—1923.

[This Drawing is a reproduction of the Original on a reduced scale]

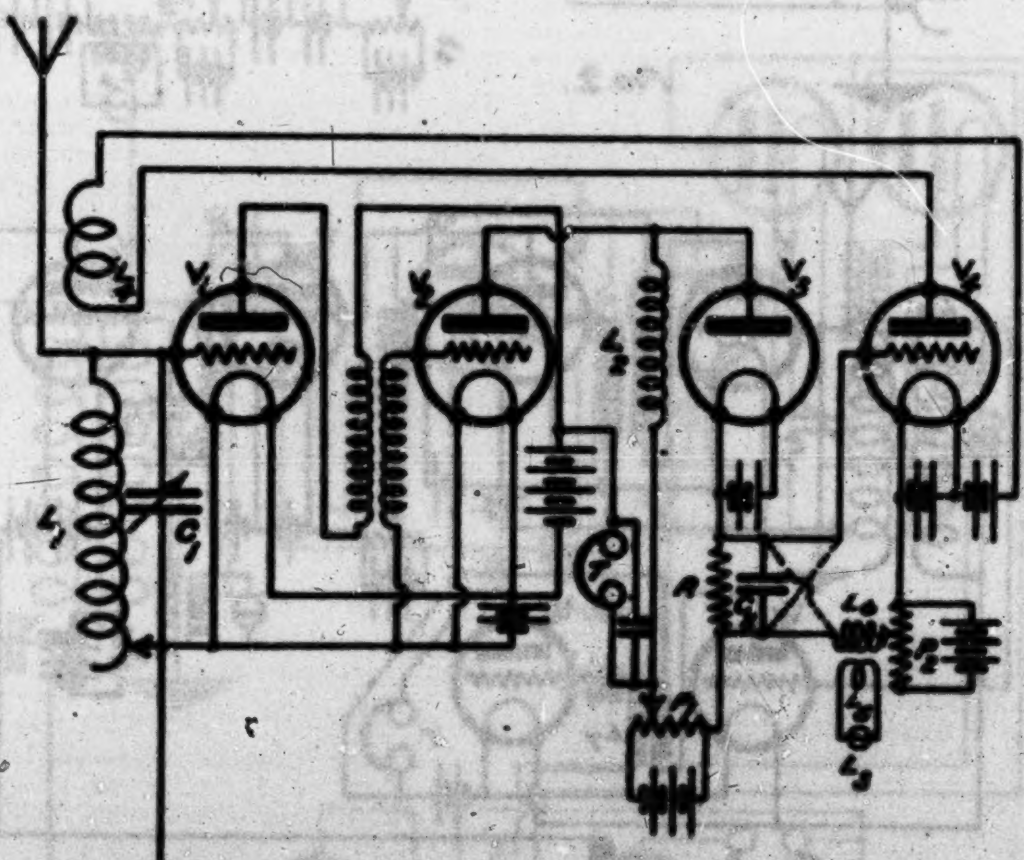

FIG. 1.

3 SHEETS
SHEET 2

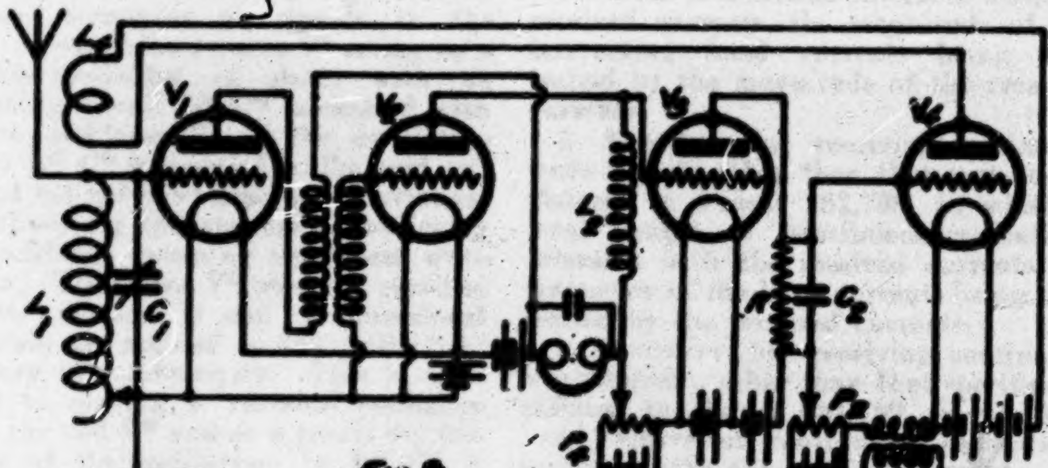

FIG. 2.

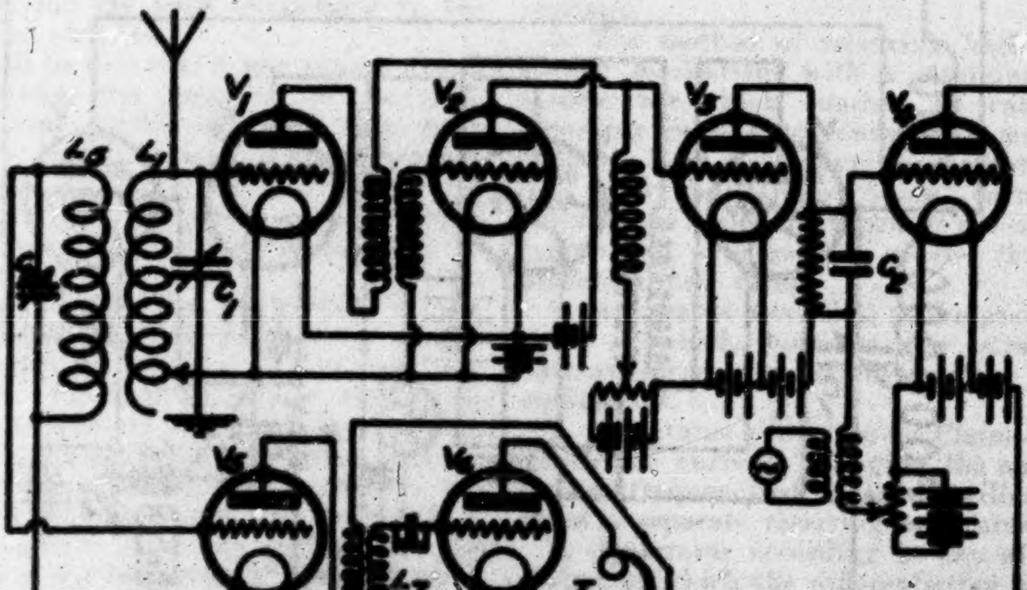

FIG. 3.

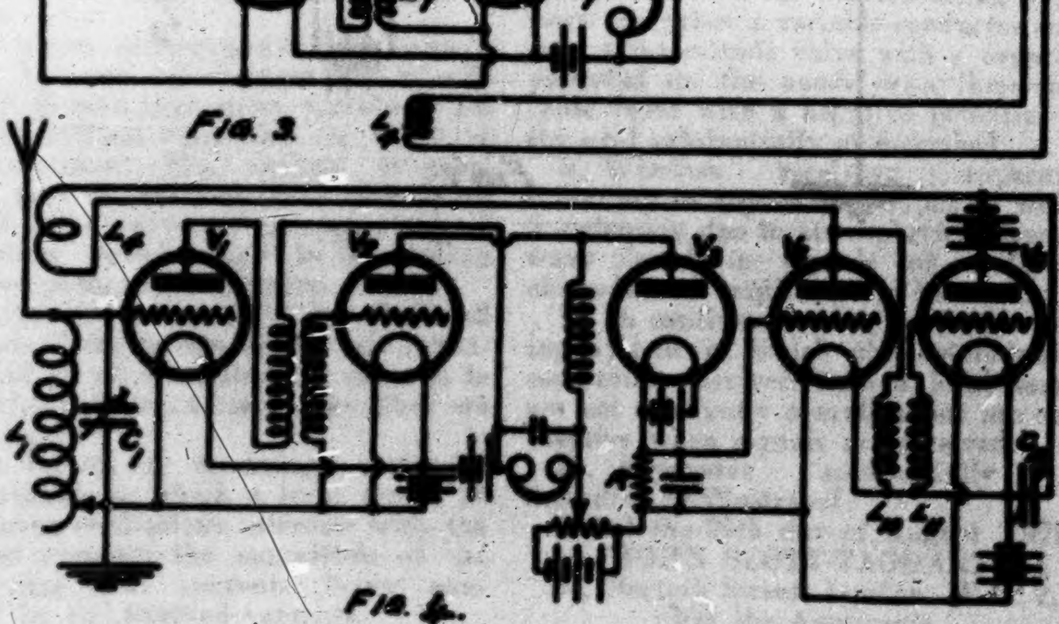

FIG. 4.

193,882 COMPLETE SPECIFICATION

3 SHEETS
SHEET 3

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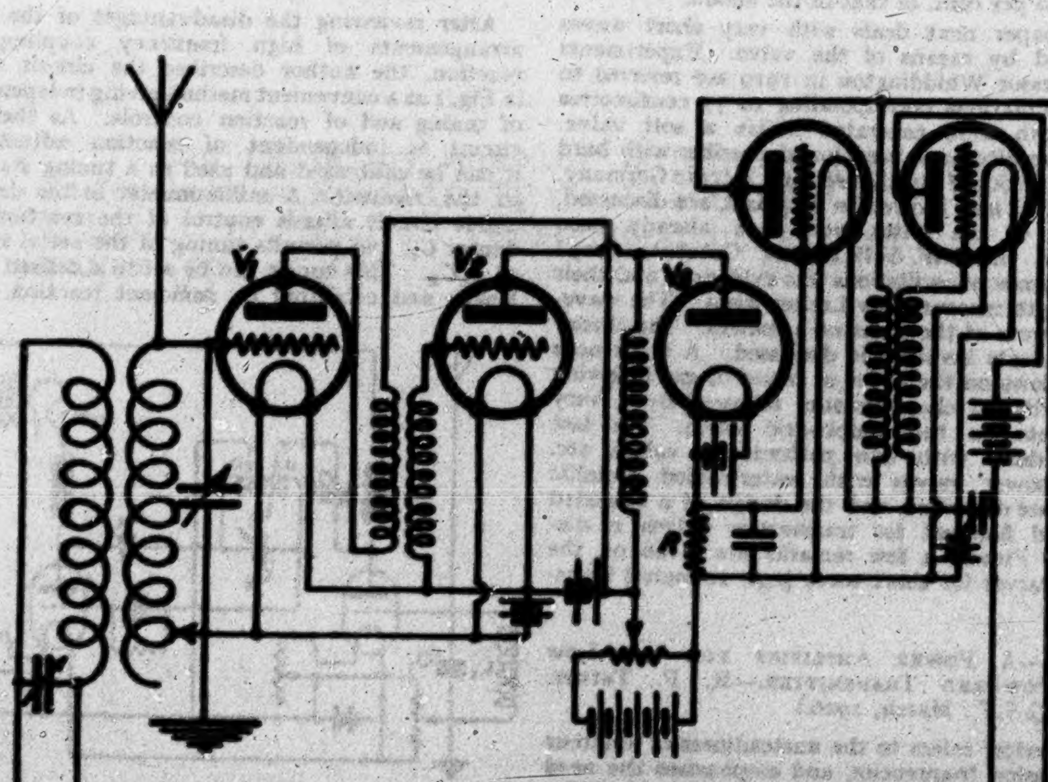

FIG. 6.

Malby & Sons, Photo-Litho

of electron absorption by the grid. The Schottky effect is discussed in some detail. This suggests that abrupt changes of anode current are not due to accidental causes, but constitute a physical phenomenon characteristic of thermionic emission. Secondary emission is then considered at some length. The literature on the subject is contradictory, and experimental tests with different valves give widely different results. The general effects of initial velocity, space charge and secondary emission are reviewed. Excessive grid potential is undesirable, resulting in heating of the grid without increase of anode output. It is pointed out that the maximum grid voltage should never exceed 80 per cent. of that of the anode.

The paper next deals with very short waves generated by means of the valve. Experiments by Professor Whiddington in 1919 are referred to when oscillations corresponding to 77 centimetres wavelength were generated *within* a soft valve. Similar results have been found possible with hard valves. Work of Barkhausen and Kurz in Germany, and of Gill and Morrell in England, are discussed. (Certain of the latter work has already been described in *E.W. & W.E.* for October, 1923.) The presence of oscillations was evidenced and their wavelength measured by Lecher wires. The wavelengths were of the order of 2 metres. The theory of the effects involved is discussed. A short note then follows on the effect of traces of gas in giving irregularity of characteristic, followed by a very brief note on the double-grid valve. The last section deals with new patterns of valves, etc. Large power valves with water-cooled metallic anodes are described, and the design of a stranded thoriated filament for transmitter valves is discussed. Finally a few remarks are given on the use of valves for short wave (*e.g.*, 20 metre) transmitters.

R342.5.—A Power Amplifier for the Low Powered Transmitter.—R. P. Turner. (*Q.S.T.*, March, 1926.)

The writer refers to the unsteadiness of amateur transmission frequencies, and emphasises the need for using a master-oscillator with a power-amplifier working to the aerial. The master-oscillator and power-amplifier elements are described. The oscillator is a Hartley circuit, with the operating key. The power amplifier is of conventional circuits, the inductance of the master oscillator being coupled to a coil in the grid circuit of the amplifier. A closed oscillatory circuit is included in the anode in the usual way and coupled to the aerial. The circuits described are for 40 metres, and details of components are given.

R342.5—Neutralising the Crystal Amplifier.—J. M. Clayton. (*Q.S.T.*, March, 1926).

It is stated that requests have been received for information as to the stabilising of the power-amplifier in a crystal controlled transmitter. The arrangement now described and illustrated is effectively that shown in Abstract "Practical Crystal-Controlled Transmitters" in *E.W. & W.E.* for March, 1926, (p. 192), where C_6 of .00025µF maximum capacity is shown as a neutralising condenser. The method recommended for de[illegible]mination of the correct adjustments for neutra[illegible]tion is to insert in the closed oscillatory cir[illegible] the Amplifier a thermal meter of 25 to [illegible] maximum. Cut off the anode volta[illegible] amplifying valve but leave the filament [illegible] milliameter will probably show some [illegible] indicating that there is "pick up" [illegible] crystal oscillator. C_6 and the tapping [illegible] inductance should be varied until ther[illegible] deflection on the milliammeter.

R342.7.—Note sur un Récepteur à [illegible]age Automatique. — J. Abelé. (*On[illegible] Élec.* March, 1926.)

After reviewing the disadvantages of the usual arrangements of high frequency coupling and reaction, the author describes the circuit shown in Fig. 1 as a convenient method giving independence of tuning and of reaction controls. As the L_2C_2 circuit is independent of reaction adjustment, it can be calibrated and used as a tuning standard in the receiver. A milliammeter in the detector anode circuit affords control of the reaction condenser C_4, and permits tuning of the aerial to that of L_2C_2. This circuit can be set to a desired wavelength and oscillated by sufficient reaction. This

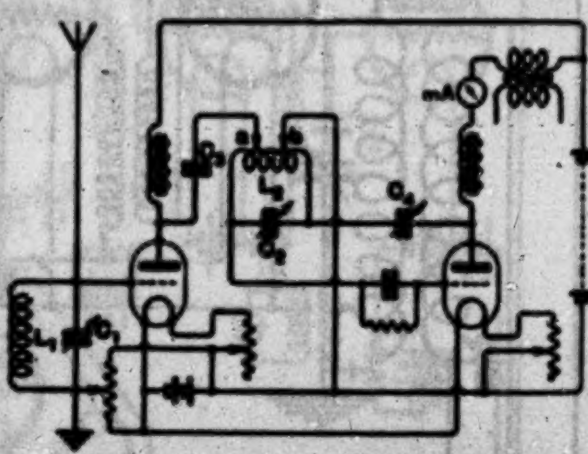

Fig. 1. *Récepteur [illegible]age automatique.*

can be checked by extinguishing the first valve, the milliammeter dropping when L_2C_2 is oscillating, and returning to its normal reading on relighting the valve. The aerial can then be tuned until the milliammeter is again a minimum, when the aerial is in tune with L_2C_2. Reaction can then be loosened to eliminate all oscillation for the reception of telephony, or to a weaker oscillation for the autoheterodyne reception of C.W. signals.

R342.7.—A Modern Regenerative Receiver.—F. Anderson. (*Q.S.T.*, March, 1926.)

The receiver described is a "straight" three valve set, using a detector with reaction from its anode, and followed by two L.F. stages. Plug facilities are provided for the use of one or of three valves. The aerial is aperiodic and coupled to a tuned secondary. Details of construction are given, including a schedule of parts, panel lay-out, coil dimensions, etc.

The paper by Wheeler which is a part of Defendant's Exhibit T, is Plaintiff's Exhibit 17, and is reproduced herein at pages 984 to 988.

AN INTERESTING SEVEN-VALVE RECEIVER

The high-class workmanship and excellent finish of this receiving installation should serve as an incentive to the experimenter to put his very best work into the instruments he may construct. Care taken in instrument-making produces reliable and valuable apparatus, whilst hurried work may give an instrument which functions, but when abandoned for another circuit arrangement can only be scrapped. The circuit principle and constructional details are of special interest.

By Murray D. Scott.

As the design and construction of this receiver has afforded the writer considerable spare time amusement, and has been of decided educational value, it is thought that a brief description may be of interest to readers of *The Wireless World and Radio Review.*

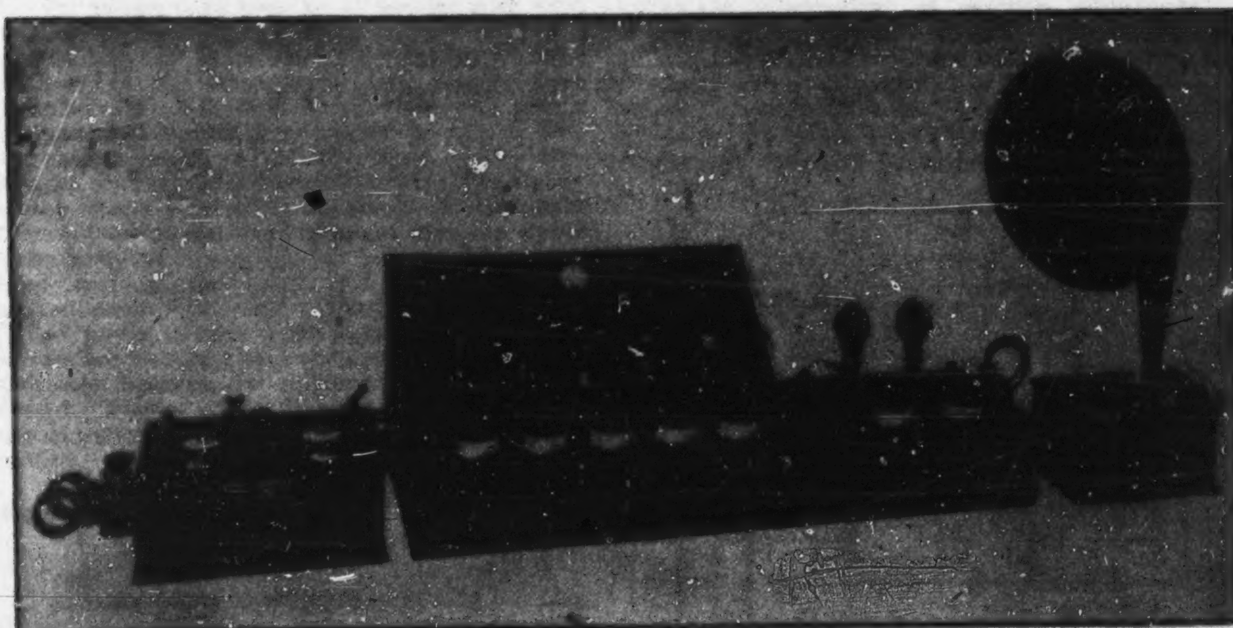

Fig. 1. The tuning unit is on the left, while the centre instrument comprises two H.F. amplifiers, detector, and two L.F. amplifiers. On the right is the power amplifier followed by the loud speaker.

The aim in design has been to secure (*a*) Selectivity; (*b*) Long range reception; (*c*) Reception from any two stations transmitting on a wavelength within 80 metres of each other by the movement of a single switch; (*d*) Distortionless reception.

The conditions governing these objectives preclude the attainment of all simultaneously, but the instrument has been designed so that the operator has at his disposal, means of obtaining each with a large measure of success, *i.e.*, for (*a*) and (*b*) the tuning arrangements allow of a high degree of resonance, with consequent low resistance.

For (*d*) the anode, grid and filament control to each valve enables the flat part of the characteristic to be worked, giving clear reception of "upper tones."

The complete receiving set (Figs. 1 and 2), comprises five units as under:—

(1) Tuner; (2) Amplifier and Detector; (3) Power Amplifier with self-contained grid, voltage control for valves six and seven; (4) Self-contained high tension batteries with stud switches, giving separate anode control for the first three and last four valves, and negative grid potential for valves four and five; (5) Low tension battery.

The units are connected together by copper link strips, and all internal connections, with the exception of those in the H.T. battery unit, are made with No. 18 gauge bare copper, and are arranged to reduce unwanted capacity effects. The headphones and loud speaker are connected by jacks and plugs.

The receiver, as at present constructed, presents a neat and finished appearance, but each component has undergone a careful test and comparison in various circuits, arranged

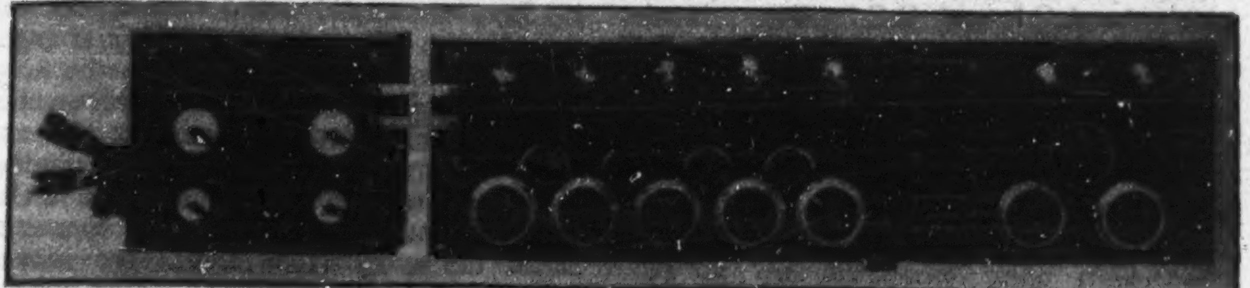

Fig. 2. The tuner, detector and amplifying units.

on a rough deal test board before assembly. The present components, before final assembly, and without the inclusion of the power amplifying unit and loud speaker, at one time occupied a board measuring 6 ft. × 4 ft.

The writer's workshop facilities being limited, the method of construction has been to use standard components wherever possible, and to make such modifications to these as experience has shown to be necessary.

The purchase of a "Magnavox" loud speaker by the time the fifth valve stage was reached necessitated a complete revision in the circuits employed, and stimulated the design and construction of the low frequency transformers, which will be described later. The purchase of this loud speaker and a milliammeter proved of the greatest educational value in the detection and elimination of distortion, and it is the writer's experience that in the majority of cases criticism levelled at a loud speaker should be more rightly addressed to the receiving instrument itself. Provided that the transmitted signals are correctly modulated, and the received signals correctly rectified, the average loud speaker, when not overloaded, will give results approximating to those obtainable with the best headphones.

Tuner Unit.

This unit, which follows generally accepted practice, is mounted in a case 13in. × 10½ in. × 5½ in., and comprises a three-coil holder for the aerial and closed circuit inductances. These inductances are tuned by condensers of 0.001 mfds. with extended handles, whilst fine tuning is obtained by vernier condensers of 0.0001 mfds. connected in parallel.

A two-way switch mounted in the centre of the tuner enables the aerial circuit condenser to be placed in series or in parallel with the aerial circuit inductance, and provision is made for regeneration when required in the anode circuit of the detector valve.

An unusual feature is the fact that both the aerial and closed circuits may be visually tuned. This is done by means of a small milliammeter mounted in the high tension unit. The accumulating negative potential on the grid of any valve is clearly recorded by the reduction in anode current shown on the milliammeter. In addition, the maximum degree of resonance in all the tuned circuits can be "seen" without listening for signals. As, moreover, the inductance coil holder is not graduated to any scale, the value of the condenser readings will vary with the variometer effect for each position of coupling, so that provided the correct value of the inductance is known for various wavelengths it is unnecessary to log condenser settings to obtain quick tuning.

The author finds that much sharper tuning can be obtained in this way than by relying on the ear. Further, tuning can be effected immediately the carrier wave is located, and before signals are actually transmitted.

Amplifier and Detector Unit.

This unit is mounted in a case similar to the tuner, size 25 in. × 10½ in. × 5½ in., and comprises two "V.24" valves for high frequency amplification, a "B" valve for rectification, and two L.S.1 valves for audio frequency amplification.

Switches are connected to give any combination from the detector valve upwards.

The coupling between the high frequency valves and the detector may be by the transformer or tuned anode method, the connections being taken into ordinary four-socket valve holders.

In order to comply with objective (c) the primary of the high frequency transformers or the anode inductances are tuned by 0.0002 mfds. condensers, arranged in duplicate. In this way two condensers for each winding are available. A switch throws either pair into operation, and when it is desired to receive

from two transmitting stations, the more distant of the two stations is accurately tuned with the A.C.I. and C.C.I. The primaries of the high frequency transformers are then brought into resonance by means of one pair of condensers. To receive from the nearer station, the other pair of condensers is then used to tune the primaries of the high frequency transformers into resonance with the new wavelength, no alteration being made on the tuner unit.

Selectivity is such that, situated ten miles north of London, items from the Glasgow broadcasting station on 415 metres, or Birmingham on 425 metres can be received at will whilst London is transmitting.

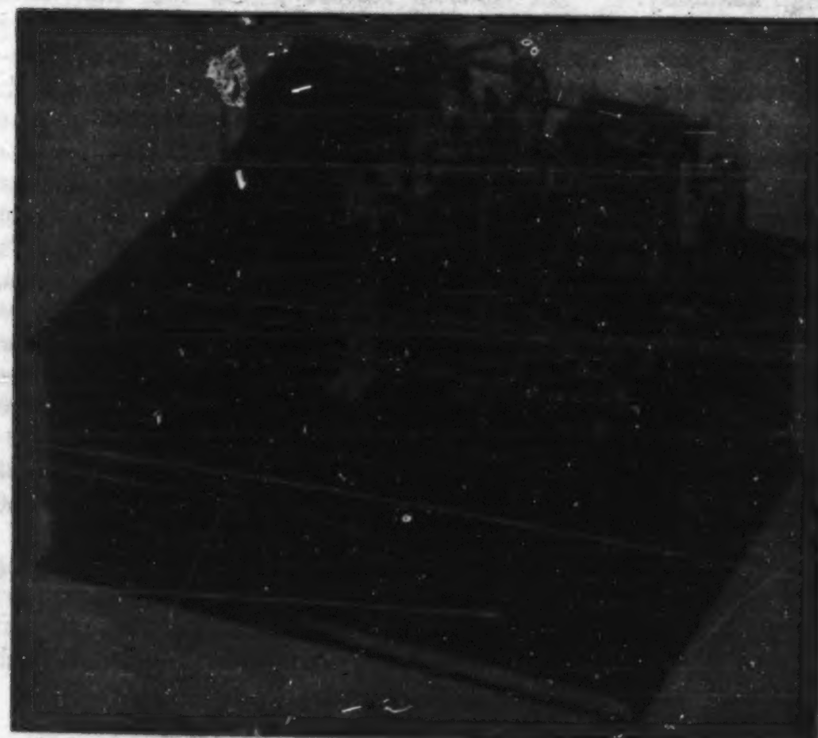

Fig. 2. Interior of the power amplifier. The unique construction of the transformers is of special interest.

A potentiometer is provided to control the grid potential of the two high frequency valves, and the anode potential is adjustable by a rotating stud switch on the high tension unit.

Rectification is carried out in the usual manner, with a leaky grid circuit of two megohms, connected between the grid and the positive low tension. No potentiometer is used.

Two low frequency amplification stages follow the detector valve. The circuits are conventional, but the selection of a transformer which could be used to couple the valves without producing undesirable distorting influences has been a matter of considerable experiment, and the one at present employed is arranged to obtain voltage amplification in the stage between the detector and the first low frequency valve. A small blocking condenser of 0.001 mfds. is connected across the primary winding to eliminate errors in rectification and a similar condenser of the same value is connected across the secondary to reduce the natural frequency of this winding. This second condenser, while it somewhat reduces the signal strength, has effected a very marked improvement in reception, especially where several further low frequency stages are used, in particular, the percussive effect of the high notes of the piano and the sibilance in speech is markedly reduced.

The second stage of audio frequency amplification is carried out in the valve itself, the transformer being simply a means of coupling. This and the following transformers were wound by the writer and consist of slab coils approximately 2 in. × ½ in. with ½ in. centre hole, each wound with No. 41 gauge single silk covered wire, to a resistance of approximately 250 ohms. Seven of these coils joined in series form the primary winding, and a similar number of coils with same gauge and resistance for secondary.

The coils are interspaced one primary, one secondary, and are mounted on a soft iron core, each coil being insulated from its fellow by means of two layers of empire cloth. The windings are clamped together with ebonite cleats, which can be seen in the illustration, (Fig. 3). A tight coupling is possible, and using "L.S.1" valves a voltage amplification of five is obtained.

When using the head telephones the impedance in the anode circuit of the last valve is adjusted by plugging the headphones in series or in parallel by means of the jacks provided. It has been found unnecessary to control the normal grid voltage of the first low

frequency valve, but a rotating stud switch, allowing a negative potential of from 3 to 40 volts is mounted on the high tension unit to control the grid of the second valve, preventing saturation and excessive "grid current."

The anode voltage of both valves is controlled by another rotating stud switch from 30 to 600 volts.

When the head telephones are employed, the switch controlling the first stage of low frequency automatically connects the telephone to the battery supplying the anode of the high frequency and detector valves. This this plate is now charged with the same anode potential as has been applied to the valve following, so that a fresh adjustment of filament emission and possibly grid potential would be necessary ofter the change is effected.

In actual practice the writer employs the same anode voltage for the last four valves, which may be, as previously explained, anything up to 600, but when the first stage of low frequency amplification is cut out, it will result in the telephones being connected between the plate of the detector valve and the high tension positive previously controlling

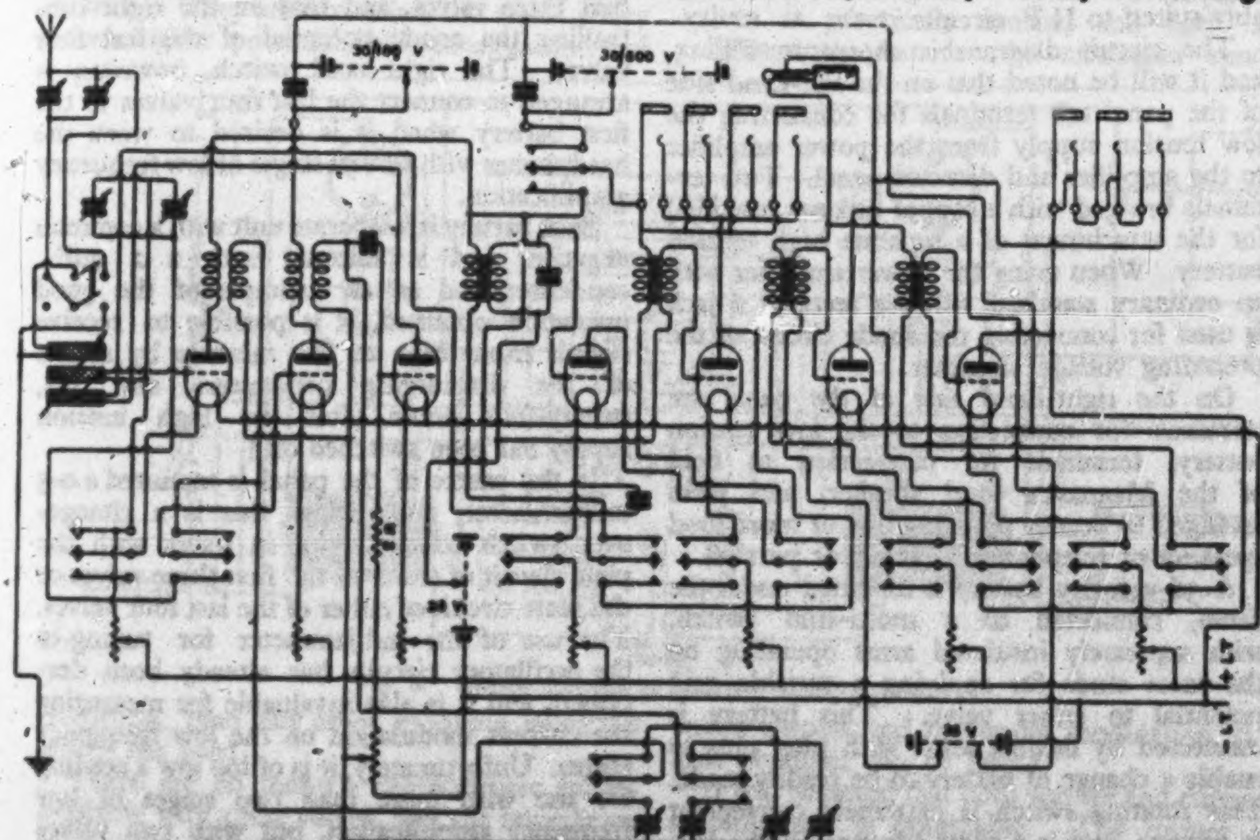

Fig. 4. Circuit of the seven-valve receiver.

switch prevents the possibility of the plate on the first three valves being energised at a potential above 100 volts. The connections of this switch are unusual, and are the outcome of a problem which became apparent as soon as separate anode voltages were available for valves. Reference to the diagram (Fig. 4) will show that the telephones or loud speaker can be connected between the positive high tension and the plate of any of the last five valves. Obviously, if each valve has been carefully adjusted as regards filament emission, grid potential, and plate voltage, the movement of the telephone leads from the plate of one valve to the one preceding it will mean that the plate of the first low frequency valve, unless special precautions are taken. In other words, when this switch is moved, both the high frequency and detector valves may be charged to a pressure of 600 volts. The solution of this problem was effected by means of the switch shown in the circuit diagram.

It will be noted that each valve has a separate filament resistance, which is mounted on the face of the panel in such a way as to dissipate heat rapidly, and prevent condensation which would otherwise occur in the unit.

Power Amplifier Unit.

The power amplifier unit is self contained in a case 13 ins. by 10½ ins. by 5½ ins, and is

arranged for two stages of current amplification, with 1:1 ratio open core transformers as previously described for coupling the two "L.S.2" valves employed.

Dewar switches not being available when this panel was made, small surface double-pole change-over switches were fitted. These switches are an improvement from the point of view of ease of connection, but a slightly larger interval occurs when changing over, and it is possible to get a shock unless carefully manipulated. The self capacity is negligible, and these switches would therefore be admirably suited to H.F. circuits.

The circuit diagram is shown in Fig. 5, and it will be noted that on the left-hand side of the panel are terminals for connecting the low tension supply from the power amplifier to the amplifier and detector panel. Two terminals bridged with a copper link are provided for the attachment of a separate high tension battery. When using the power amplifier with an ordinary standard wireless receiver a jack is used for connecting the anode circuit of the preceding voltage amplifier.

On the right-hand side of the panel are terminals for connection to the low tension battery, terminals for connection to field of the Magnavox loud speaker, and jacks arranged to permit plugging one or more loud speakers or telephones in series or parallel.

A 36-volt dry battery is mounted under the panel, connected to a multi-stud switch, with separately insulated arms operating on the same studs for applying a variable grid potential to either valve. This battery is connected by flexible leads with plug pins to enable a change of battery to be readily made. This rotating switch is extremely convenient to operate, and is a great advance on the employment of a wandering plug, or separate stud switch for each valve.

Loud Speaker.

The loud speaker employed is a standard "Magnavox" junior, except that it has been mounted in a mahogany case to match the receiver, and means have been provided for controlling the natural frequency of the diaphragm or armature by means of :—

(1) Change-over switch fitted in the field circuit, so arranged that the polarity of this field may be reversed.

(2) A rheostat in the field circuit arranged so that the amplitude of the diaphragm oscillation may be controlled.

Normally no adjustment whatever is necessary to the Magnavox as purchased provided that the input to the instrument is undistorted. The modifications described will be found an improvement when it is necessary to clarify signals owing to interference.

High Tension Unit.

The high tension unit shown in Fig. 1 is contained in a case 25 ins. by 10½ ins. by 12½ ins. with a sloping front panel. On the panel are mounted three stud switches, the one on the left controlling the anode potential of the first three valves, and that on the right controlling the anode potential of the last four valves. The right-hand switch, however, is arranged to connect the last four valves to the first battery when it is desired to work the headphones with several stages of low frequency amplification.

Each battery is a separate unit with a common negative, and is shunted with a 2 mfds. condenser, and as an example of the good insulation obtained, it is possible to receive signals from three to five minutes by means of the discharging condensers, and this, twenty-four hours after the high tension supply has been switched off!

In the centre of the panel is mounted a 0-5 milliammeter, and below this is a change-over switch connecting it in series with the plate circuit of either of the first three valves or the plate circuit of either of the last four valves. The use of the milliammeter for tuning-in the oscillatory circuits has already been described, and it is also invaluable for measuring the current modulation on the low frequency stages. Unfortunately, it is of too low a reading for use with more than two stages of low frequency amplification, but with two valves in circuit it records to 2 to 2½ milliamps modulation in the anode circuit. The Paris time signals are invariably recorded visually in this way. Contained in this unit also is a separate battery for supplying negative grid potential to the first two low frequency valves. A seven-stud switch will be seen to control this feature.

Valves.

The selection of a most suitable valve for the function which it is desired to perform is most important, and it is to be regretted that so little information is available from the valve manufacturers in this country. When characteristic curves are obtainable, they are seen to be based on "average" results, and th

writer finds it desirable to prepare a characteristic of each valve and to check this from time to time as the valve softens.

The "V.24" valve is very suitable for high frequency amplification on short wavelengths, but it is extremely critical—a very slight alteration in anode potential or filament emission is quite sufficient to completely interrupt signals. This valve, also, is not very economical.

For rectification the "R.4B" valve has been found most suitable, although the ordinary "R" valve, if moderately soft, gives good results.

For audio-frequency amplification both the "L.S.1" and "L.S.2" valves give very good service. They are expensive, but allow a very much higher potential, without saturation and distortion, than any other receiving valve the writer has used.

There are no maker's characteristic curves available with these valves, and the impedance of various specimens varies tremendously. It is, therefore, absolutely essential to have grid voltage control to each valve.

It is most desirable to employ a separate high tension battery for the "high frequency and detector" and the "low frequency stages." Until this battery was separated a considerable amount of distortion arose, due to comparatively large current taken by the power valve, causing a slight drop of voltage on the plate of the high frequency valves. This distortion was brought to light by a milliammeter placed in circuit with the high frequency anode.

The best tuning adjustment when found is recorded visually on the milliammeter. Should it then be desired to switch in a further low frequency stage a very slight drop in filament potential will occur with consequent reduction in the anode current. Unless this is noted and corrected by decreasing the filament resistance of the "V.24" valves a loss of signal strength will result. With the use of the milliammeter it is a simple matter to increase the filament current until the ammeter needle reaches the previously recorded reading. The writer also uses the milliammeter to ensure that the best portion of the characteristic curve of the detector is being worked on.

The D.C. component on the low frequency valves is practically useless, and until the milliammeter records the minimum steady anode current and maximum modulation, the grid potential can be raised.

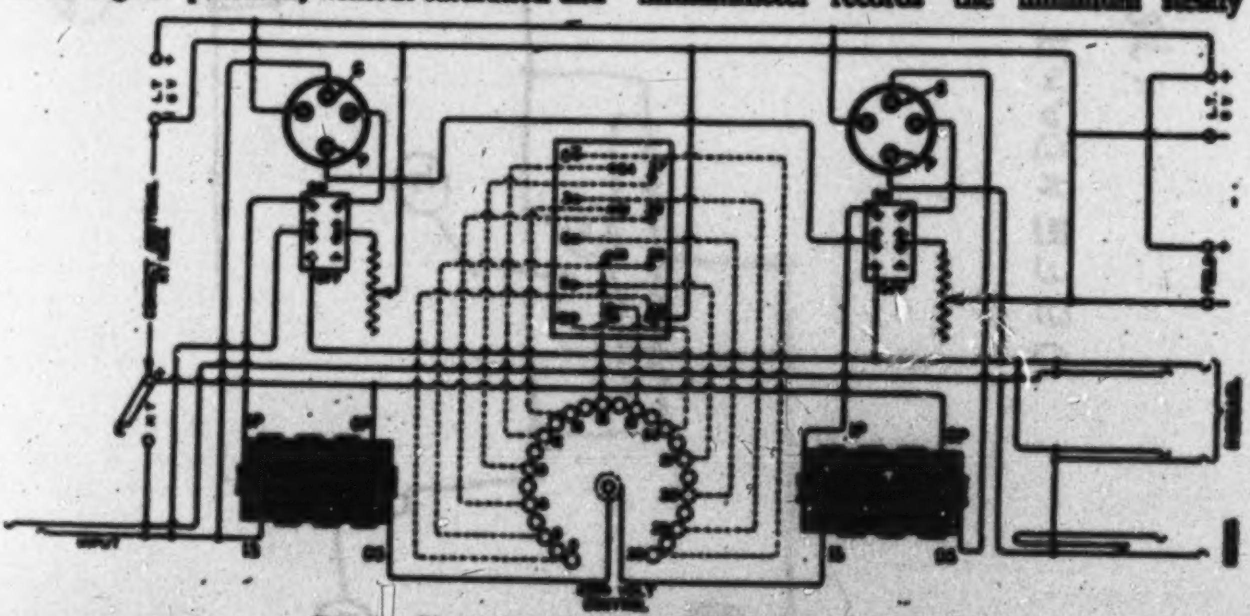

Fig. 5. Circuit diagram of two-valve power amplifier.

It will be noted that both voltage and current amplification is obtainable. The former is preferable with head telephones, and loud speakers constructed on the telephone receiver principle. It has been found that current amplification produces very little increase in sound volume when this type of loud speaker is used.

With the moving field loud speaker further stages of current amplification produce a very noticeable increase in the volume of sound.

Although there are 51 separate controls on this receiver, it is by no means unmanageable. Care is needed with the high frequency amplification stages, and, of course, with the reaction circuit when this is employed. The writer's daughter, aged 6, regularly tunes in and listens to 2 LO, using the detector valve only.

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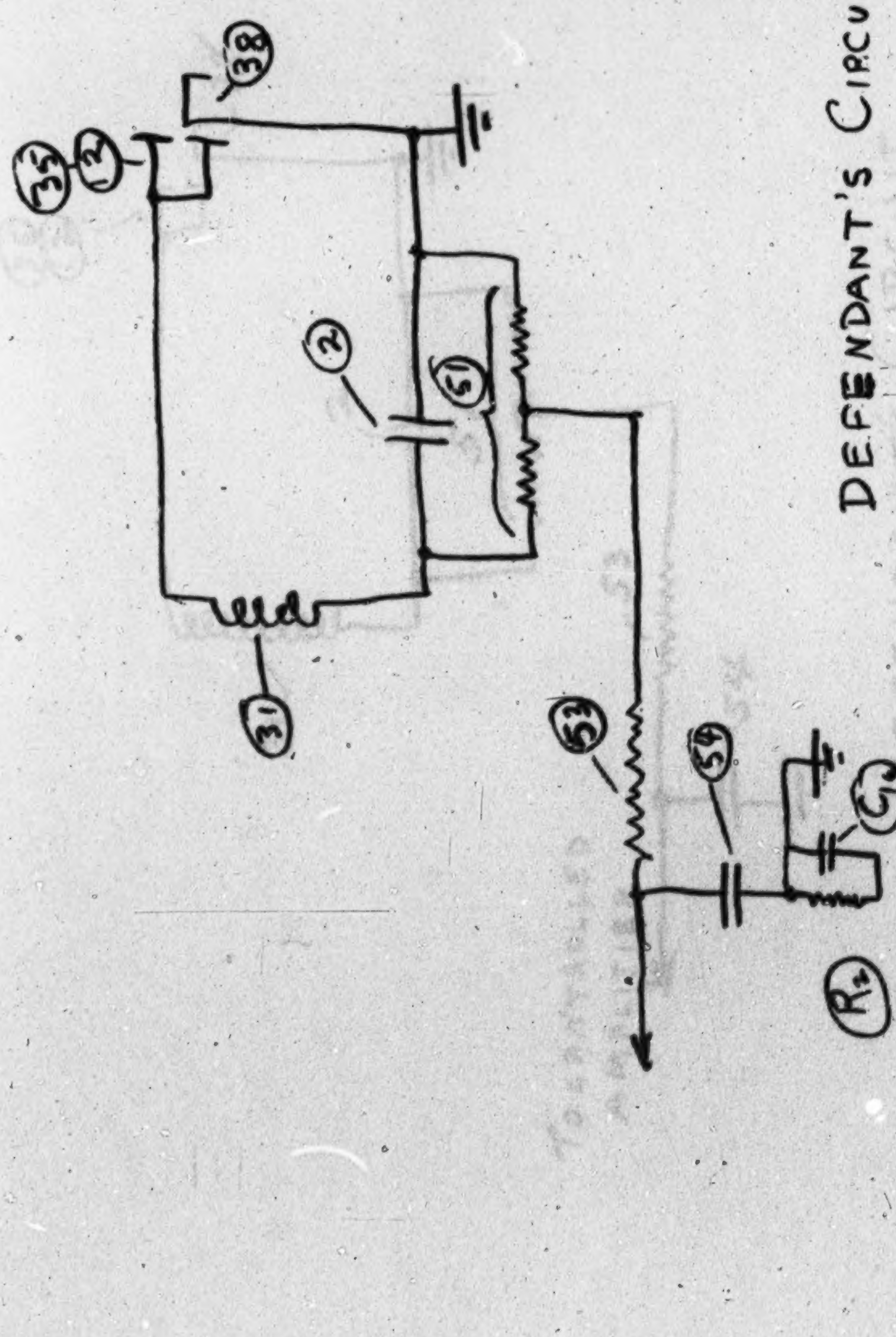
DEFENDANT'S EXHIBIT U



DEFENDANT'S CIRCUIT
175

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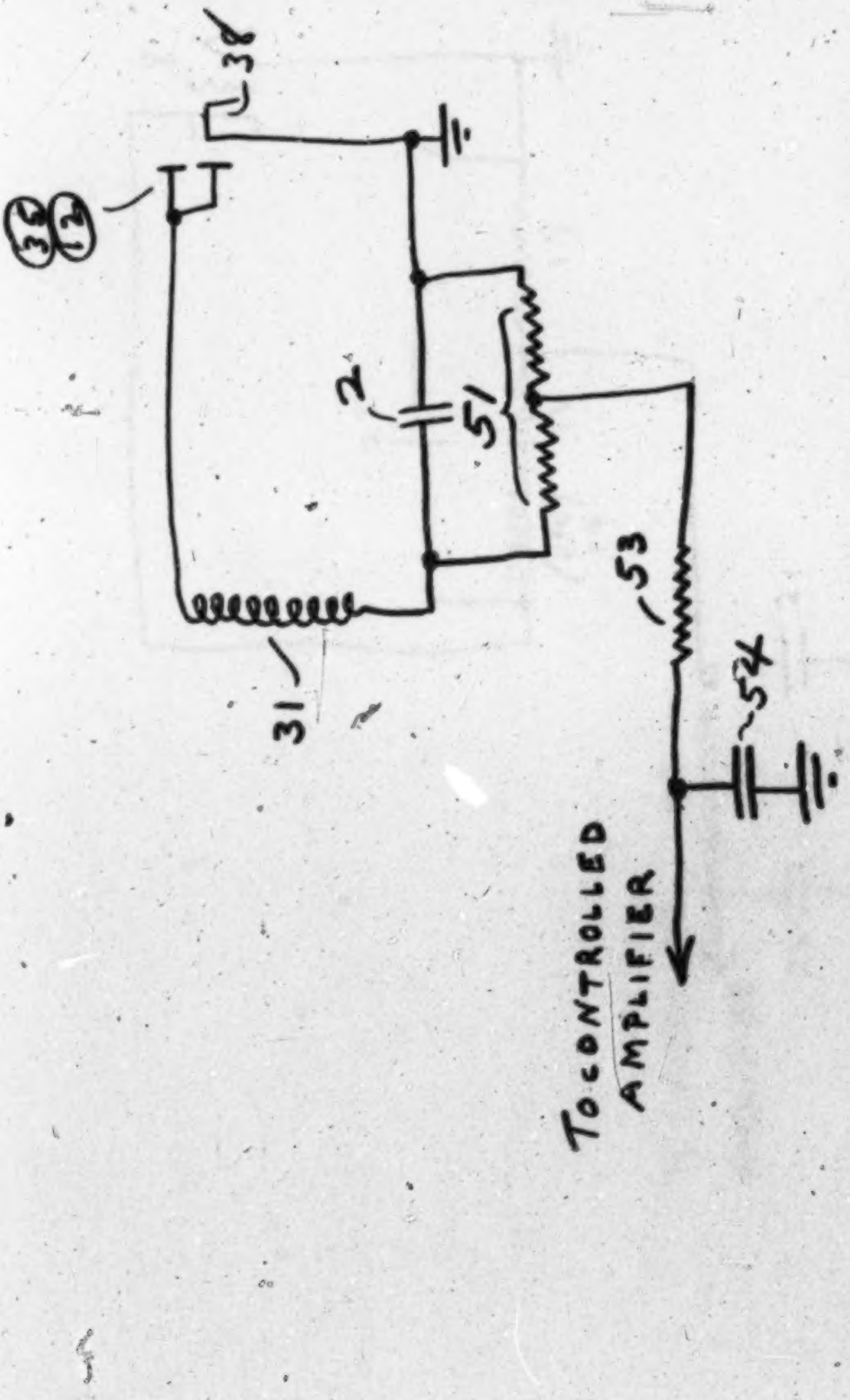
DEFENDANT'S EXHIBIT V



DEFENDANT'S CIRCUIT

178

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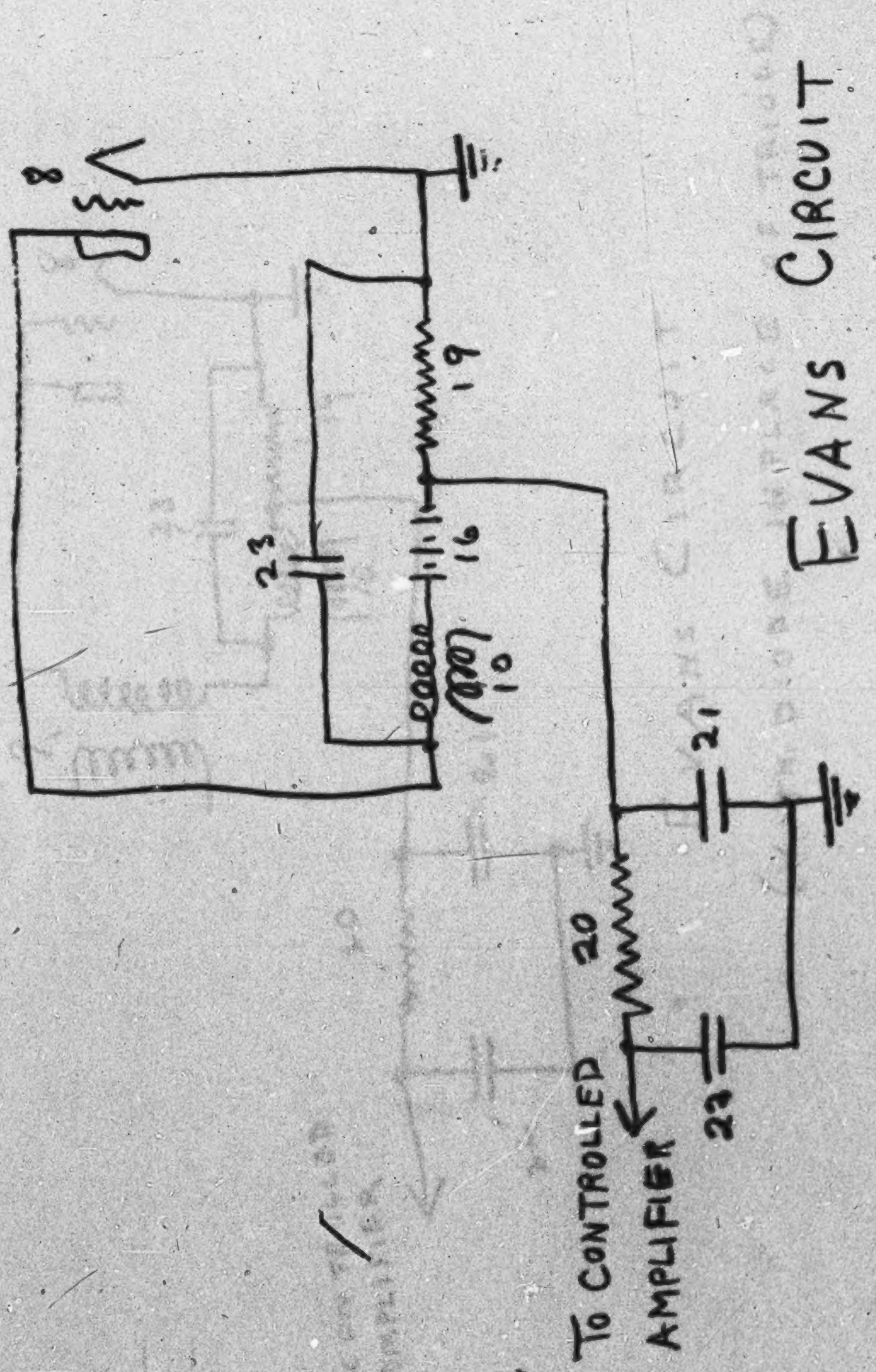
DEFENDANT'S EXHIBIT W



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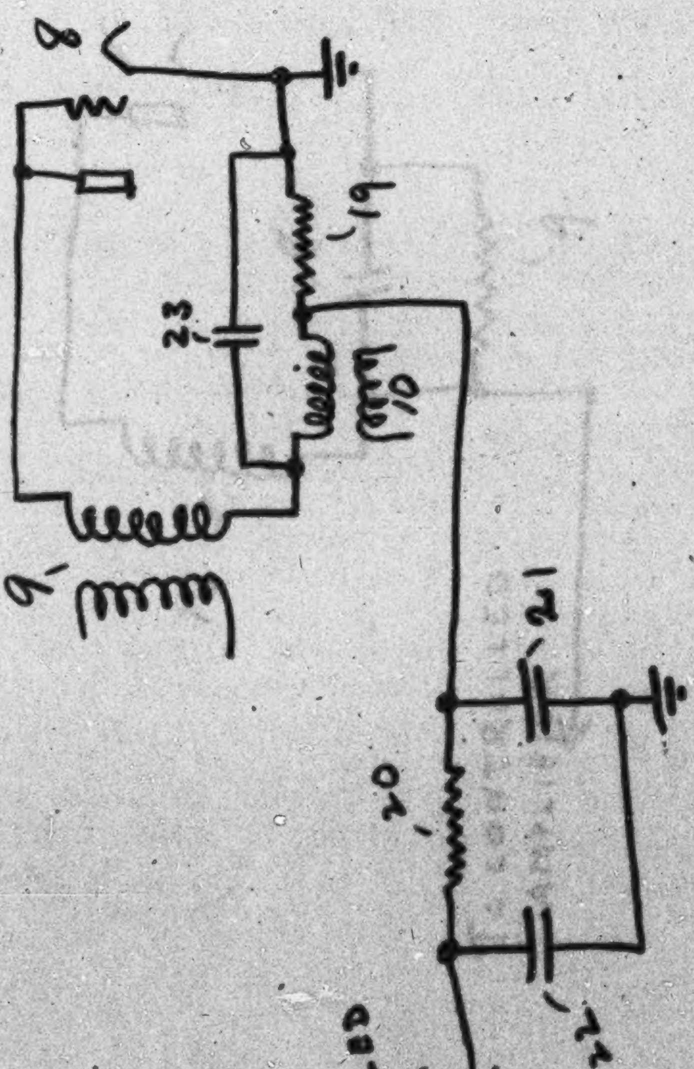
DEFENDANT'S EXHIBIT X



EVANS CIRCUIT

(WITH DIODE IN PLACE OF TRIODE)

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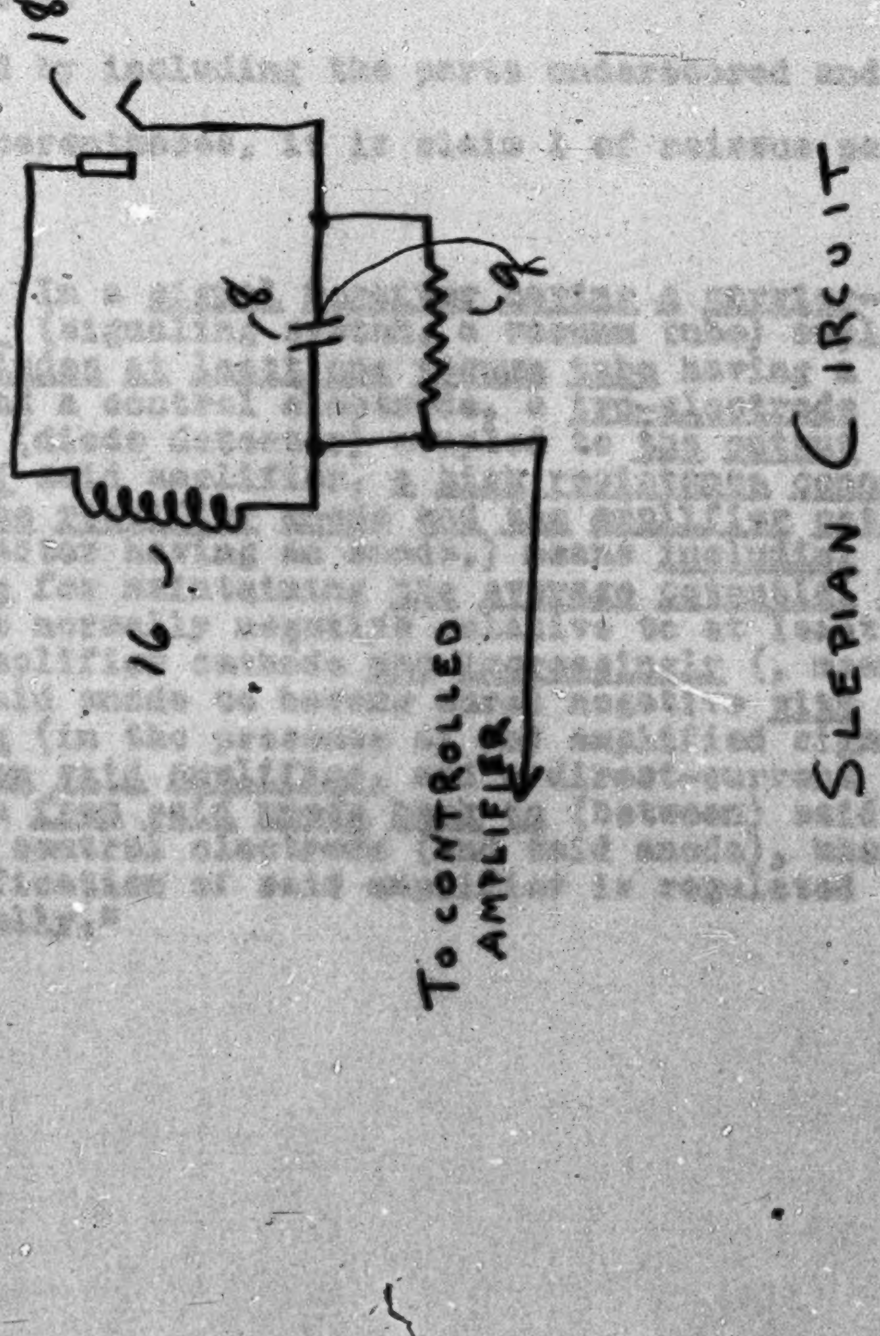
DEFENDANT'S EXHIBIT Y

This claim, read by including the parts in parentheses and omitting the parts underscored, is claim 13 of patent 1,879,863.

Read by including the parts underscored and omitting the parts in parentheses, it is claim 1 of reissue patent 19,744.

"1. In a signal receiver [illegible] (signaling [illegible] vacuum tube) amplifier [illegible] having a cathode and a control electrode, [illegible] diode detector [illegible] a high resistance connected between [illegible] and said amplifier cathode, (said detector having an anode,) means including said resistance for maintaining the average potential of said anode normally negative relative to at least part of said amplifier cathode [illegible] (, means for causing said anode to become [illegible] negative [illegible] (in the presence of) amplified signal output from said amplifier, [illegible] direct-current connection from said anode [illegible] (between) said amplifier control electrode (and said anode), whereby the amplification of said amplifier is regulated automatically."



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DEFENDANT'S EXHIBIT Z

This claim, read by including the parts in parentheses and omitting the parts underscored, is claim 10 of patent 1,879,863.

Read by including the parts underscored and omitting the parts in parentheses, it is claim 1 of reissue patent 19,744.

"1. In a signal receiver having a carrier-frequency, (signaling system, a vacuum tube) amplifier which includes at least one vacuum tube having a cathode and a control electrode, a two-electrode rectifier (diode detector) coupled to the output circuit of said amplifier, a high resistance connected between the rectifier anode and the amplifier cathode, (said detector having an anode,) means including said resistance for maintaining the average potential of said anode normally negative relative to at least part of said amplifier cathode and increasingly (, means for causing said anode to become more) negative with increasing (in the presence of an) amplified signal output from said amplifier, and a direct-current connection from said anode back to (between) said amplifier control electrode (and said anode), whereby the amplification of said amplifier is regulated automatically."

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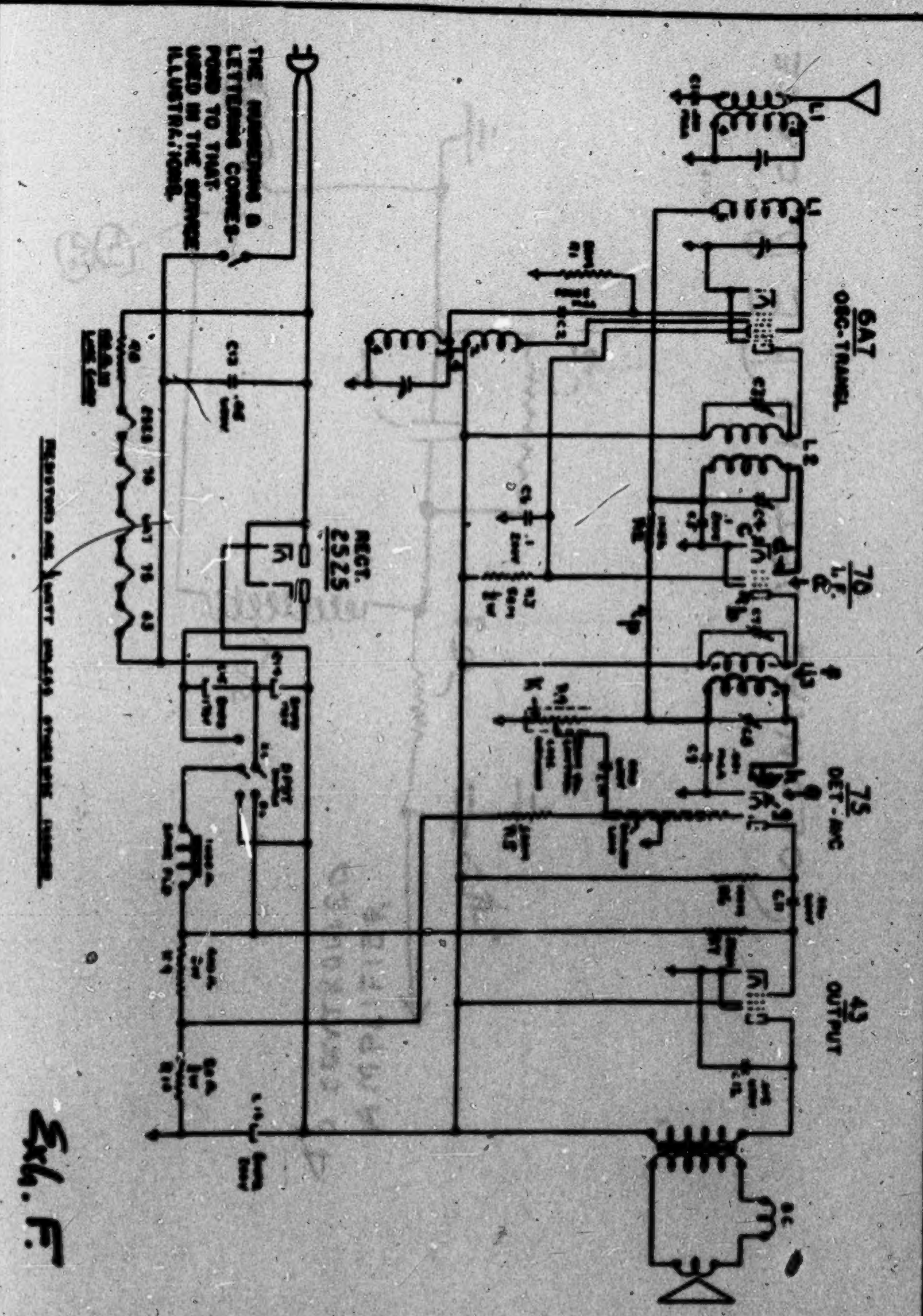

FIG. 24. SCHEMATIC - MODELS 250 - 300 (Extended Range AC-DC)

Tightly Bound

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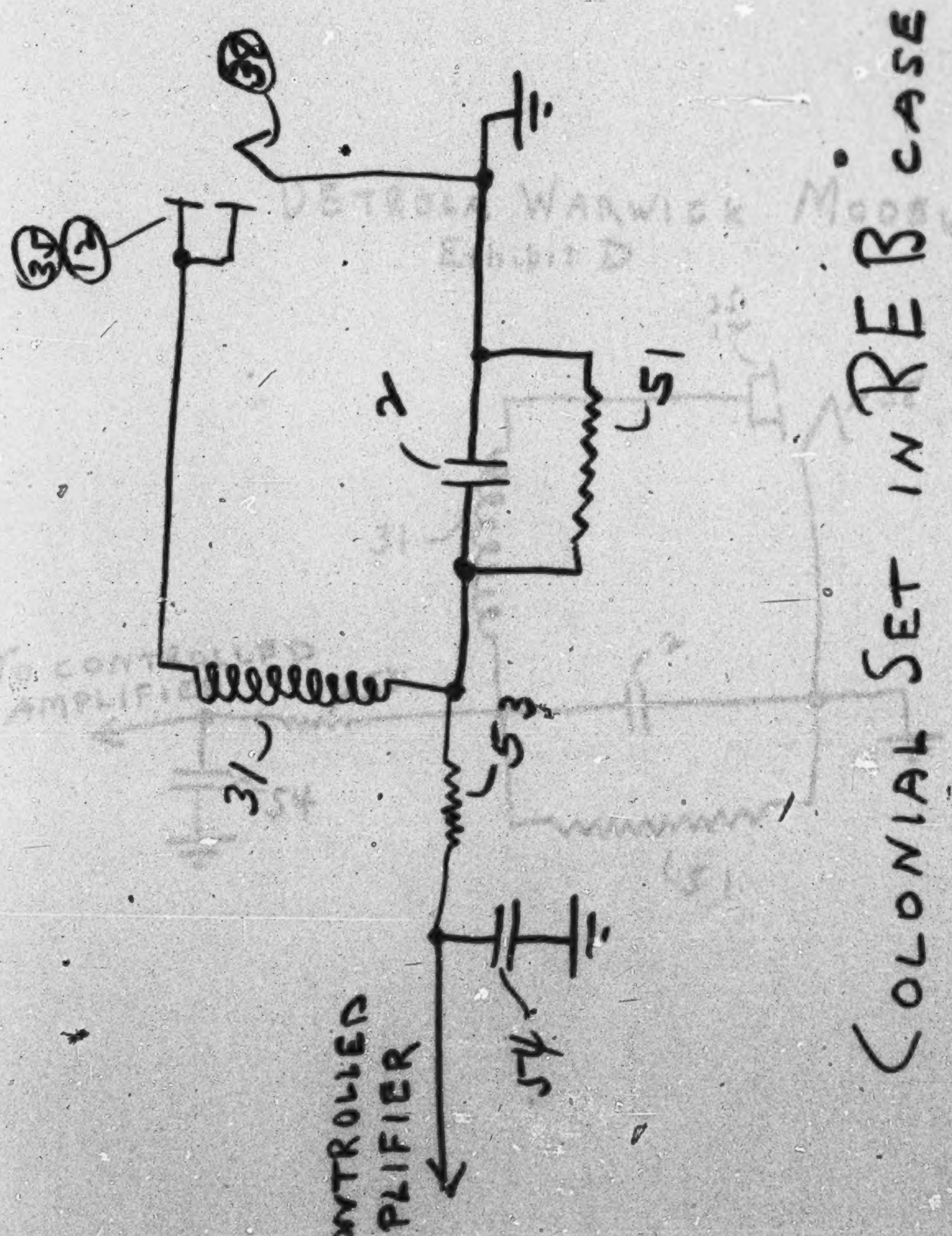
DEFENDANT'S EXHIBIT BB



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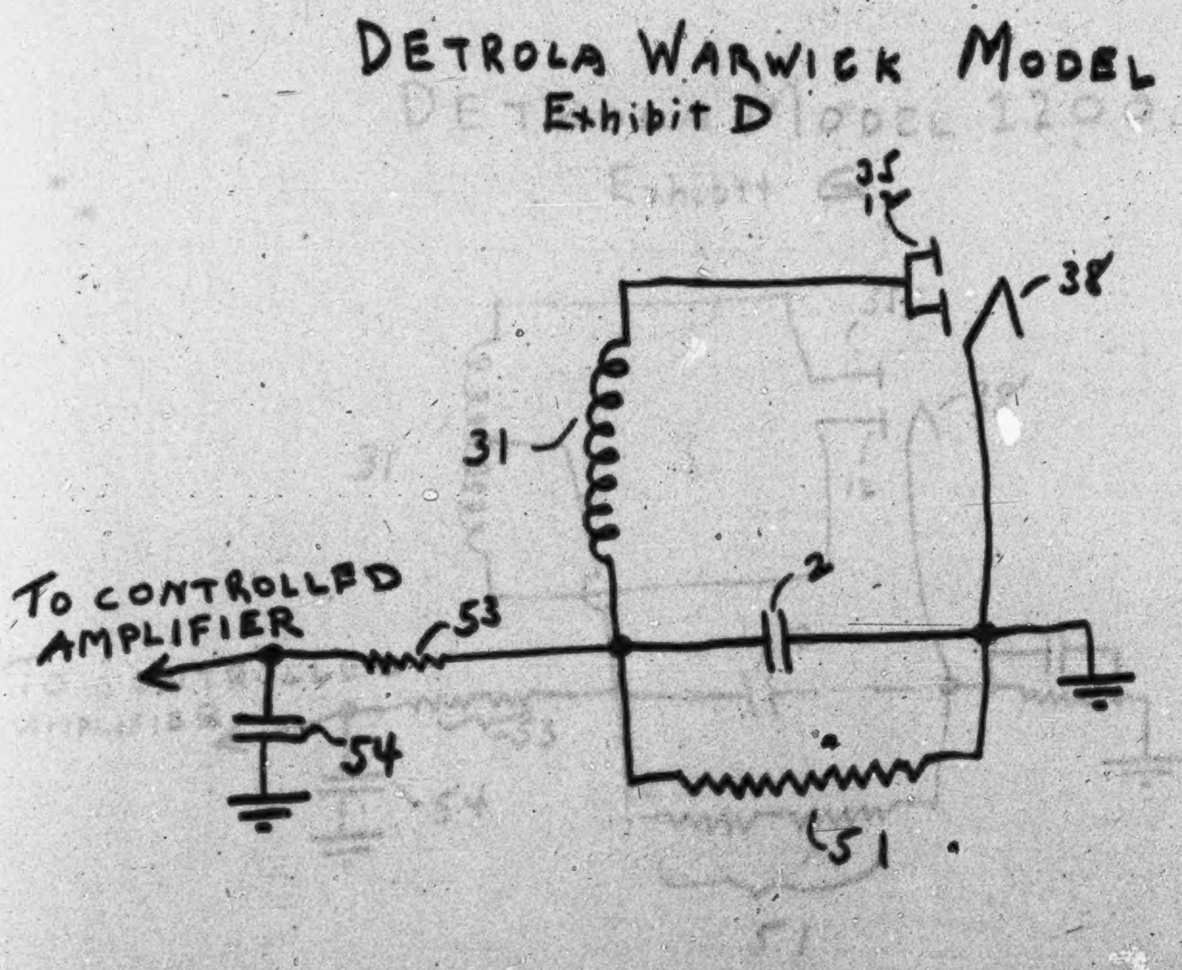

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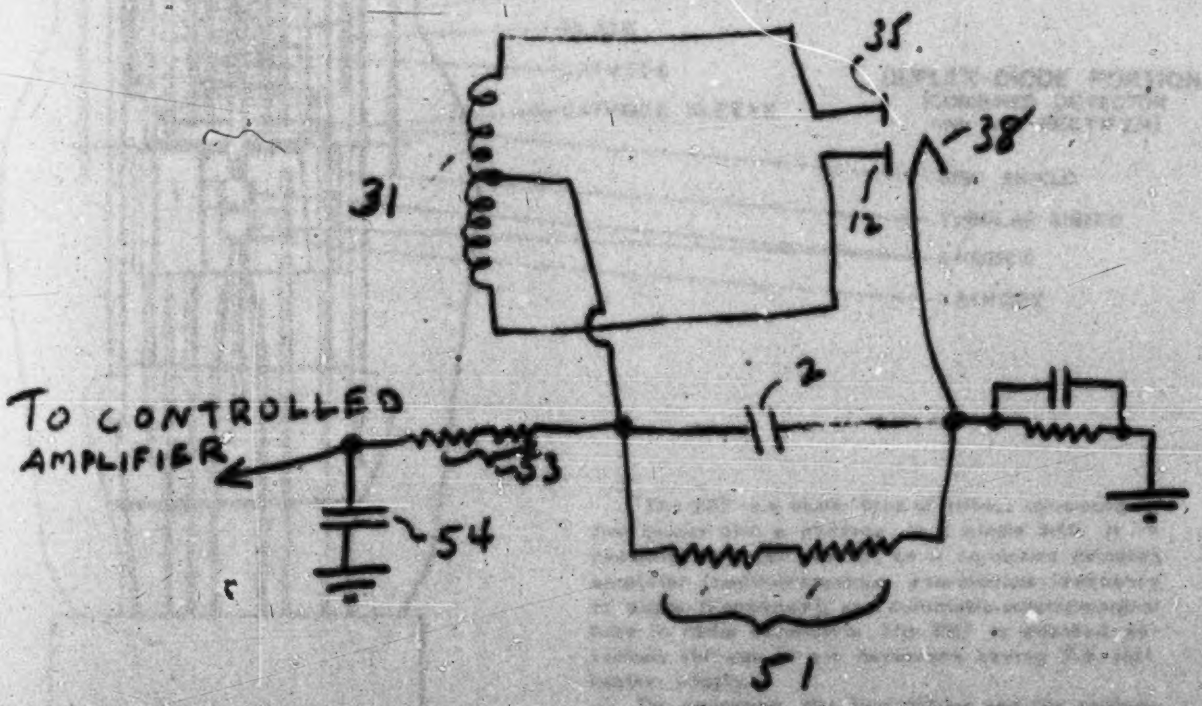
DEFENDANT'S EXHIBIT DD

DETROLA MODEL 1200.
Exhibit G



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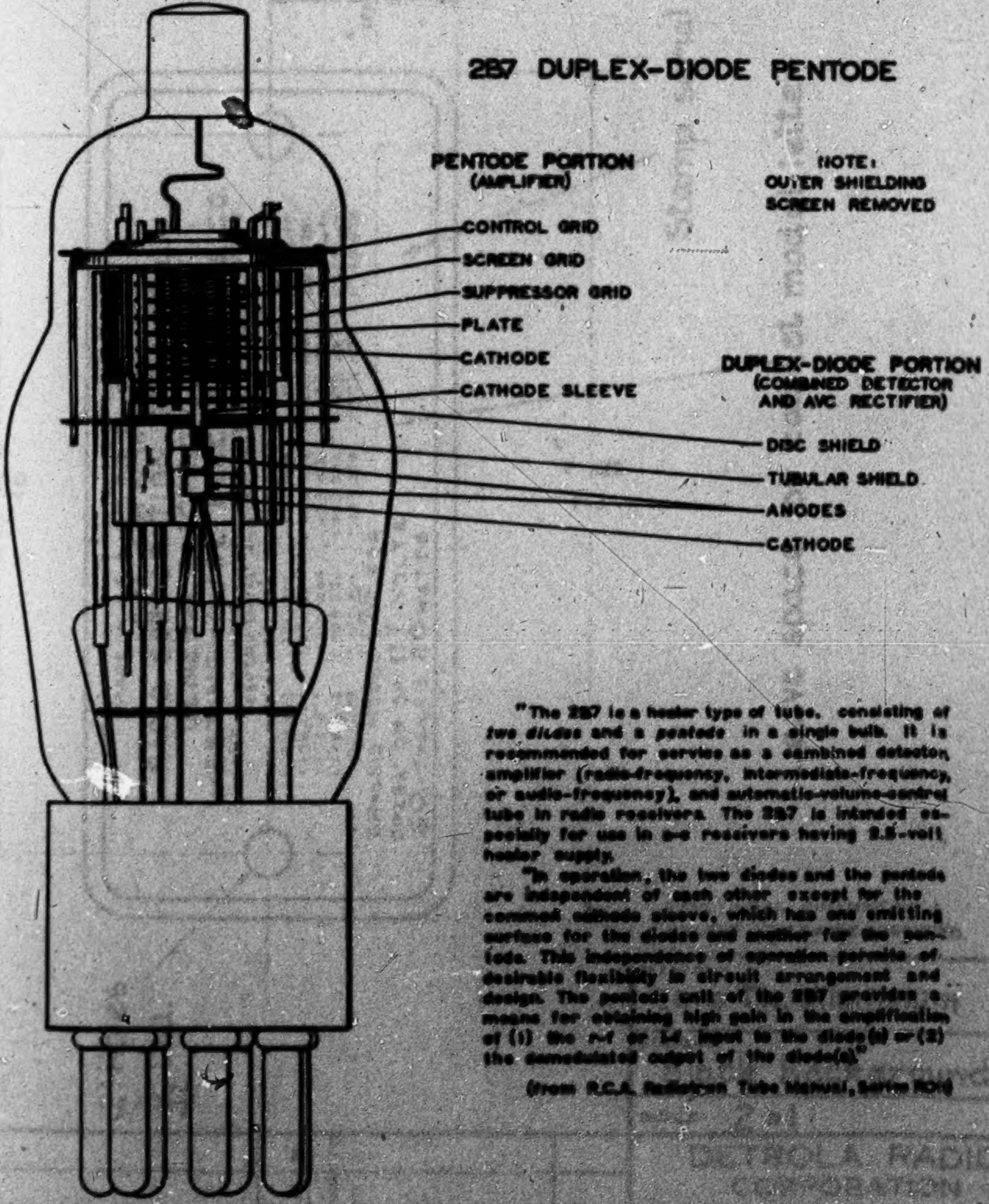
DEFENDANT'S EXHIBIT EE

2B7 DUPLEX-DIODE PENTODE



"The 2B7 is a heater type of tube, consisting of *two diodes* and a *pentode* in a single bulb. It is recommended for service as a combined detector, amplifier (radio-frequency, intermediate-frequency, or audio-frequency), and automatic-volume-control tube in radio receivers. The 2B7 is intended especially for use in a-c receivers having 2.5-volt heater supply.

"In operation, the two diodes and the pentode are independent of each other except for the common cathode sleeve, which has one emitting surface for the diodes and another for the pentode. This independence of operation permits of desirable flexibility in circuit arrangement and design. The pentode unit of the 2B7 provides a means for obtaining high gain in the amplification of (1) the r-f or i-f input to the diode(s) or (2) the demodulated output of the diode(s)."

(from R.C.A. Radiotron Tube Manual, Series RC11)

RHL. 40808-2

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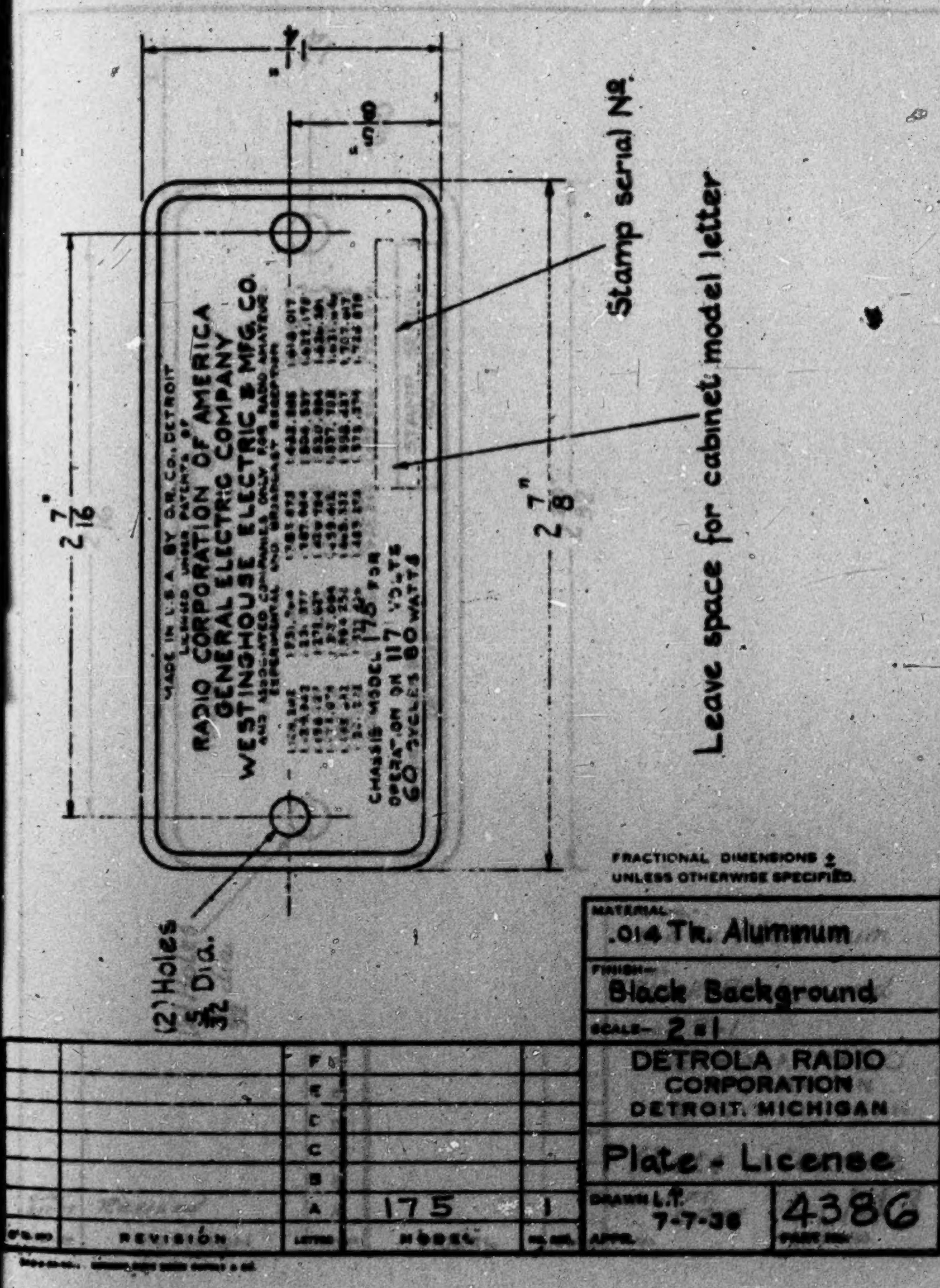

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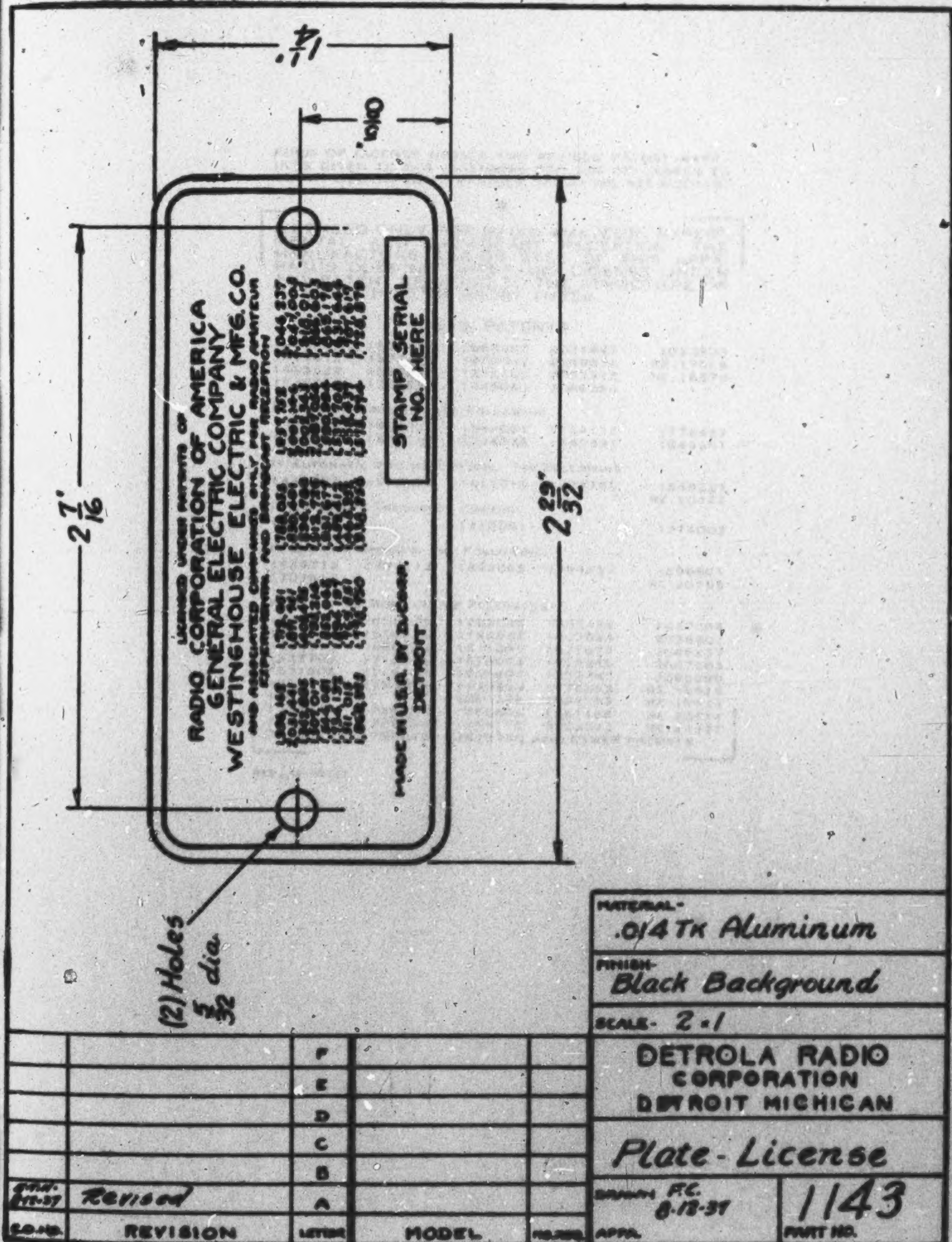

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DEFENDANT'S EXHIBIT HH

FORM OF LICENSE NOTICE AND REVISED PATENT MARKINGS GIVEN TO RCA LICENSEES FOR USE ON LABELS TO BE APPLIED TO THEIR VARIOUS RECEIVING SET MODELS.

LICENSED ONLY FOR RADIO AMATEUR, EXPERIMENTAL AND BROADCAST RECEPTION. THE MANUFACTURE AND/OR SALE OF THIS APPARATUS DOES NOT IMPLY ANY LICENSE UNDER ANY PATENT RELATING TO THE STRUCTURE OR MANUFACTURE OF RADIO TUBES.

U. S. PATENTS

1403932	1558437	1868443	2031441	2092893
1459412	1573374	1920342	2048814	RE. 17909
1465332	1631646	1936162	2052316	RE. 18579
1537708	1702833	1945040	2066284	

IF SUPERHETERODYNE, THE FOLLOWING:

1484605	1507017	1544081	1734132	1778457
1507016	1508151	1734038	1740331	1849651

IF AUTOMATIC VOLUME CONTROL, THE FOLLOWING:

1447773	1510698	1511015	1574780	1869323
				RE. 20442

IF AUTOMATIC FREQUENCY CONTROL:

1642173		1712051		1774003

IF DYNAMIC SPEAKER, THE FOLLOWING:

1639713	1795214	1852068	1894197	1899581
1707617				RE. 20155

ALSO ONE OR MORE OF THE FOLLOWING:

1403475	1654075	1788035	1907478	2027054
1411814	1658346	1794957	1907555	2038401
1448550	1668724	1811095	1931677	2046237
1527703	1712036	1828094	1938256	2047003
1531805	1719161	1830401	1957752	2086595
1559679	1728879	1835934	1976558	RE. 18916
1561892		1861222	1982777	RE. 19945
1572083	1769851	1866603	2001146	RE. 20114
1596198	1778750	1869175	2002343	RE. 20307
1618017	1787946	1896780	AND OTHER PATENTS.	

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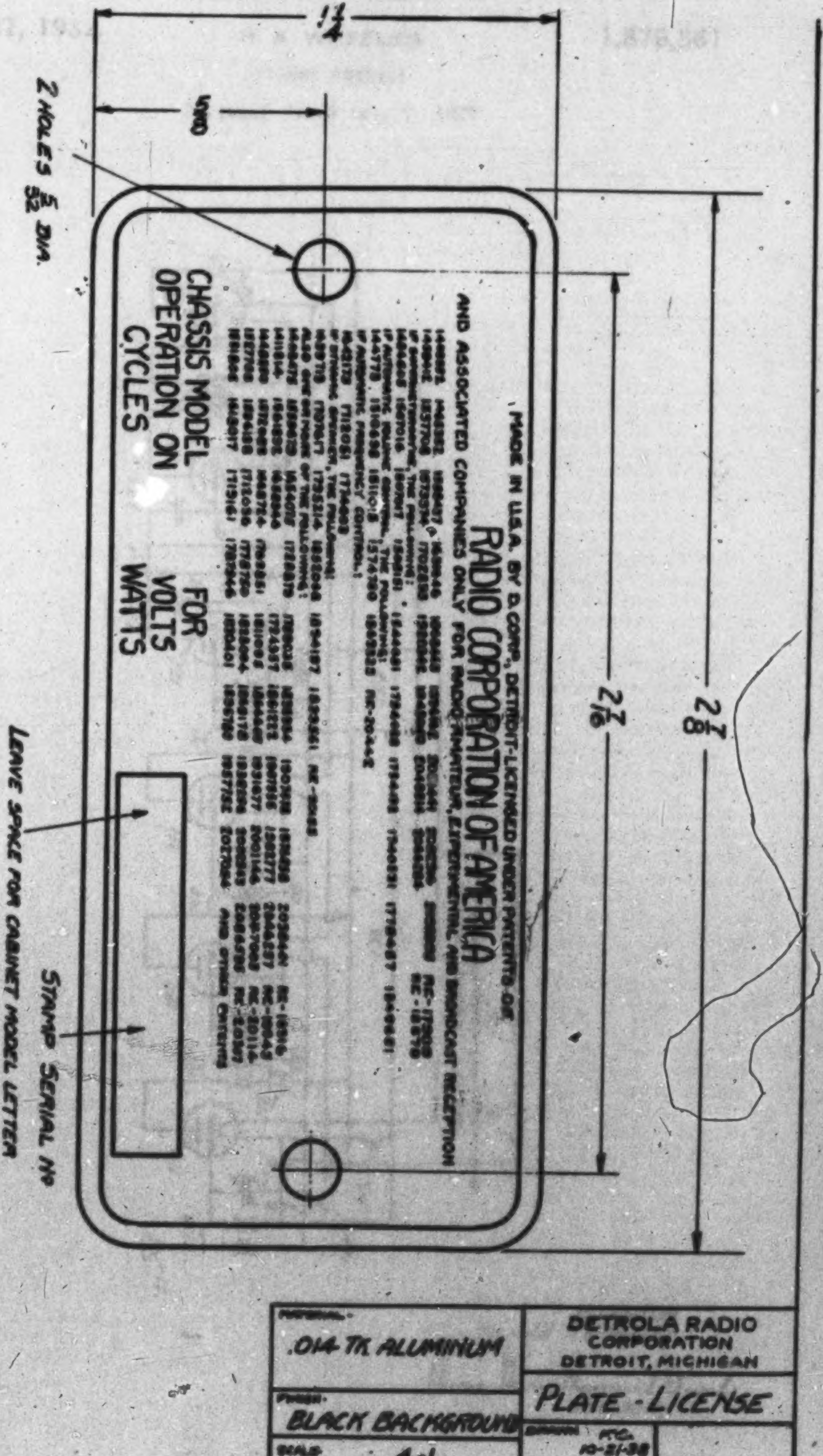
DEFENDANT'S EXHIBIT II



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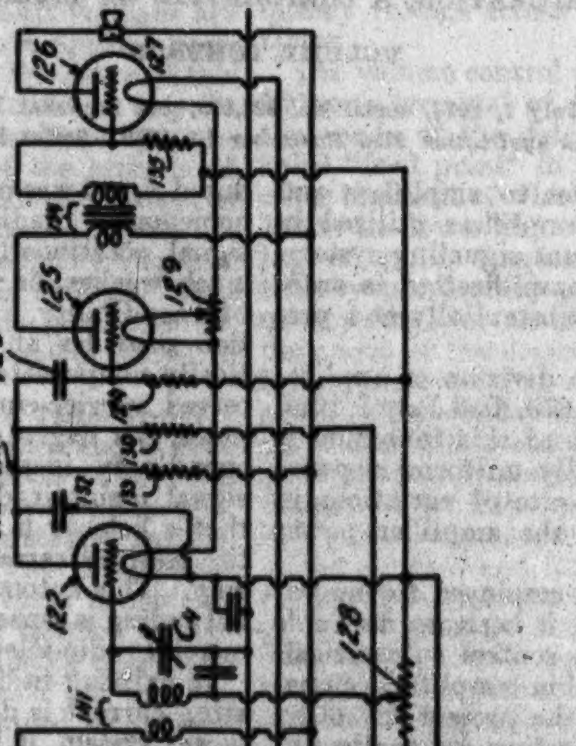
DEFENDANT'S EXHIBIT JJ

Sept. 27, 1932. H. A. WHEELER 1,879,861

VOLUME CONTROL

Original Filed July 7. 1927



INVENTOR
Harold A. Wheeler
BY
Pennie, Davis, Marvin and Edmonds
ATTORNEYS

Patented Sept. 27, 1932 1,879,861

UNITED STATES PATENT OFFICE

HAROLD A. WHEELER, OF JACKSON HEIGHTS, NEW YORK, ASSIGNOR TO HAZELTINE CORPORATION, A CORPORATION OF DELAWARE

VOLUME CONTROL

Original application filed July 7, 1927, Serial No. 203,879, and in Great Britain July 5, 1926. Divided and this application filed November 10, 1930. Serial No. 494,582.

This invention relates to amplifiers and more particularly to amplifiers utilized in modulated carrier-current signaling systems wherein the limit of amplification is automatically maintained substantially at a predetermined level.

This application is a division of application Serial Number 203,879, filed July 7, 1927.

The principal object of this invention is to obtain a substantially uniform response from an amplifier in spite of variations in signal intensity or of the amplifier power supply.

When amplifiers are employed for amplifying a signal voltage, it becomes desirable for various reasons, to control automatically the amplitude of this amplified signal voltage. To this end the present invention provides means for effecting automatic amplification control. Such an arrangement, for example, is particularly advantageous in radio receivers such as are employed for receiving broadcasting signals, because it prevents the overloading of the last amplifier stage of the receiver, which overloading would result in distortion of the reproduced signal, as well as in loud and harsh reproduction.

Another advantage of the invention resides in uniform reproduction of the amplified signal irrespective of whether the carrier-current signal is received from a nearby station or from a distant station, or from a high power or from a low power station, since it has been found in the case of former radio receivers that when the receiver was reproducing strong signals as from a nearby or high power station, the audibly reproduced signal was very loud, whereas when the signal was received from a distant or low power station, it was relatively weak, with the result that if signals were to be reproduced uniformly from both near and distant stations, and from high power and low power stations, it became necessary to readjust some volume control means in the receiver to compensate for these unequal signals.

It has been a common experience in the use of former radio receivers, that the reproduced signal was not uniform, due to the phenomenon of "fading", whereby the received signal occasionally or periodically became much weaker, or faded almost to the point of inaudibility. Since the present invention provides an amplifier which automatically compensates for inequalities in the received carrier-current, when fading takes place, the degree of amplification is correspondingly increased and the reproduced signal maintained at its former volume so that a listener is unaware that variation of the received carrier current signal is occurring. This automatic compensation for signal fading is especially advantageous in commercial radio-telephony and like systems.

In existing radio receivers in which operating current is derived from the municipal power system, it has been found that when there is considerable variation in the line voltage supply, the volume of the reproduced signal is not uniform. An additional advantage of the present invention is that of automatically compensating for such line voltage variations with the result that the reproduced signal is uniform in volume.

Still a further advantage is the saving in plate current which is automatically effected during the reception of the powerful signals, for the reason that this invention incidently provides means for reducing the plate current of one or more amplifying tubes as the signal strength increases.

The above advantages are attained in accordance with the present invention by employing in the signal receiver a rectifying, or detecting, device preceded by one or more stages of carrier frequency amplification and impressing the potential of a point in the detector output circuit upon a control circuit of the carrier frequency amplifier. This is preferably accomplished by connecting a point in the detector output circuit, preferably the anode, through an impedance, or carrier frequency filtering arrangement, to the control electrode of one or more carrier frequency amplifying tubes, which then acts as the volume controlling tube or tubes. The circuit is so arranged that the potential of the control electrode of the volume controlling tube is

normally negative with respect to its filament. An increase of the signal strength, then, increases the rectified signal component, thereby making the control element of the volume controlling tube more negative, thereby reducing the amplification.

A feature of the invention is the provision of a source of potential supply for the electrodes of the vacuum tubes, which source includes resistances across which voltages are developed, which voltages are applied upon the proper tube electrodes. By virtue of this arrangement, the detector cathode may be maintained at a potential considerably negative with respect to that of the cathode of the amplifier whose amplification it is desired to control and the output electrode of the detector may be maintained slightly negative with respect to said amplifier cathode. This relationship of the electrode potentials enables the automatic volume control circuit to properly operate.

The drawing illustrates a radio receiver operated by a source of rectified and filtered alternating current, the receiver comprising three stages of radio frequency amplification, a rectifier, or detector and two stages of audio-frequency amplification. The three radio frequency stages comprise three thermionic amplifiers, 119, 120 and 121 coupled in tandem, the output of tube 121 being coupled to a three-electrode detector tube 122, and the input of tube 119 being coupled to antenna 137. The tubes are coupled in a well-known manner by transformers 138, 139, 140 and 141, the secondary windings of which are tuned by variable condensers C_1, C_2, C_3, and C_4. The variable condensers are grounded to eliminate undesirable capacity effects and to enable the condensers to be ganged together and operated by a uni-control arrangement. The audio-frequency amplifier comprises vacuum tubes 125 and 126 coupled in tandem by an audio-frequency transformer 134, the secondary winding of which has shunted across it, a resistance 135, the effect of which is to improve the uniformity of amplification over the voice frequency range.

The output of tube 126 is connected to a loud speaker 127, or if desired, to some other type of receiving device, such as a meter or a telephone system. The first audio-frequency amplifying tube 125 is connected to the output of the detector through an audio-frequency network or impedance coupling, which transmits the audio-frequency signals to the audio amplifier. This coupling comprises a condenser 123 connected between the anode, or plate, of the detector and the control electrode, or grid, of the amplifier tube 125, and an impedance 124, capable of transmitting direct current connected between the same grid and a source of grid biasing voltage.

The anode potential is supplied to the plate of the detector through a resistance 133, which is connected between a source of anode potential and the detector plate.

There is provided a condenser 132 connected between the anode and cathode, or filament, of the detector, this condenser being adapted to by-pass the radio frequency without appreciably shunting off the detected signals. Condenser 132 acts in conjunction with resistance 133 to diminish the radio frequency voltage across the output of the detector.

The volume control comprises a resistance 130, one terminal of which is connected to the anode of the detector, at the point labeled "feed point" in the drawing, and the other terminal of which is connected by lead 136 to the lower end of the secondary winding of radio frequency transformer 138, thereby placing the grid of the radio frequency amplifier 119 at the same potential as the anode of the detector. A condenser 131 bridged between the lower end of the secondary winding of transformer 138 and ground, cooperates with resistance 130 to prevent the passage of radio frequency energy from the output of the detector to the input of the radio frequency amplifier.

The rectified and filtered alternating current power supply for the receiver has shunted across its output three resistances, "A", "B" and "C" series, across which are respectively derived filament, plate and grid "B", and "C" voltages for the receiver. The filaments or cathodes of the six vacuum tubes are connected in series across the "A" resistance of the rectified, filtered, source of power supply, giving a potential difference of 30 volts, this being the proper voltage when the normal filament voltage of each tube is five volts.

The filament of the audio-frequency amplifier tube 126 is shunted by potentiometer 129 which acts as a manual volume control. The anode potential for all the tubes is derived from a connection to the positive end of resistance "B". It should be noted that the cathode of the first radio-frequency tube 119 is connected to the positive terminal of the 30 volt "A-section" of the power source, and that the cathode of the detector tube 122, is connected to the negative terminal of this section. In consequence, when the voltage across resistance B is 90 volts, the voltage available in the plate circuit of the detector is 120 volts with respect to its filament, while that available in the plate circuit of the first radio frequency amplifier is 90 volts with respect to its filament. The value of resistance 133 is high and is so chosen that the D C voltage drop across it due to the normal plate current through it, is greater than 90 volts, thus placing the detector anode, or "feed point", at a negative potential with respect to the cathode of radio frequency amplifier 119. The grid biasing potential of the first radio frequency tube, then, is negative with

respect to its cathode. The volume controlling system is operative so long as the detector anode is negative with respect to at least a part of the filament of the amplifier 119. The large value of resistance 133 required by this circuit arrangement results in high sensitivity of the detector circuit.

It should be understood that the invention is not limited to the use of the voltage values herein expressed; but these values are given merely to indicate how good results may be obtained.

In the event that tubes having an indirectly heated cathode are used instead of those having an electric current heated filament cathode, as represented in the drawing, the same results may be obtained as in the system illustrated in the drawing, if the detector cathode is maintained at a negative potential with respect to the cathode of the volume control tube, or tubes.

There is provided in the plate circuit of tube 119 a milliammeter 116 for indicating the anode current of that tube. A switch 115 serves to connect the lead 136 to the cathode of tube 119 when desired. The functions of the milliammeter and of the switch will be more fully disclosed later.

To complete the description of the system illustrated in the drawing, certain design data, or constants, are given herewith. It should be understood, however, that these, as well as all other constants appearing in the present specification are mentioned merely by way of example in describing certain specific embodiments, which, in practice, should prove satisfactory, and are not intended to suggest any specific limitation as to the scope of this invention. Accordingly, condenser 132 may be of .0005 micro-farads; 131 of .1 micro-farads; 128 of .005 micro-farads; resistance 133 of .5 megohm; and 130 and 124 of 2 megohms each.

In the operation of this receiver, a signal received by the antenna 137 is successively amplified through the three radio frequency amplifier stages. The audio-frequency signals with which the radio frequency carrier wave is modulated, are then detected in a well-known manner by detector 122, which is a grid bias detector. The audio-frequency signals are successively repeated by audio-amplifying stages comprising thermionic amplifiers 125 and 126, after which they are reproduced as sound by loud speaker 127.

A detected signal current flowing through resistance 133 causes the plate of the detector to become less positive relative to its cathode, and hence causes the potential of the grid of radio frequency amplifier 119 to become more negative relative to its cathode, thus decreasing the amplification of this amplifier stage. The stronger the incoming signals become, the more negative becomes the grid of amplifier 119, and the more the amplification is reduced. Conversely, when the signals become weaker the amplification increases. The result of this is that the strength of the signals impressed upon the detector remains nearly uniform for widely different signal strengths.

The automatic volume control not only compensates for fluctuation in the strength of the incoming signals, but also compensates for variations in the line voltage of the alternating current power supply. A drop in the line voltage, for example, reduces the current through resistance 133, thereby reducing the negative potential on the grid of tube 119 and increasing the amplification. Conversely, the increase of power line current makes the grid of the first radio frequency amplifier more negative.

In this manner, the radio frequency voltage applied to the input of the rectifier detector is maintained at nearly constant predetermined value, and the volume of the reproduced signal is substantially uniform under all conditions. The degree of volume of the reproduced signal is then determined by adjustment of potentiometer 129, which controls the heating current in the filament of the first audio-frequency amplifying tube 125.

In adjusting the system for reception, it is necessary to determine the correct setting of the detector grid potentiometer 123. This adjustment should be made while there is no signal being received, as follows: First, the switch 115 is closed and the normal plate current of the tube 119 is noted on milliammeter 116. Then the switch is opened, thus placing the control circuit in operation. In general, the plate current of vacuum tube 119 will change when the switch is opened since the grid voltage of this tube is dependent upon the control circuit. By varying the grid voltage of the detector by means of potentiometer 123, the plate current of tube 119 is then adjusted to normal value, and the apparatus is ready for operation. Upon receipt of an amplified signal at the detector, the effect of the control circuit is to decrease the plate current through the milliammeter thereby reducing the amplification of the tube 119. When the receiver is tuned to the signal frequency a minimum amplification is required so the condition of resonance is ascertained by a minimum reading of the milliammeter.

It is possible to employ in place of the three-electrode detector, a two-electrode rectifier or detector, in the manner set forth in my above mentioned application, Serial Number 203,879. An advantage of the three-electrode detector over the two-electrode type is its greater response to weak signals.

It is understood that the invention is not limited to the specific embodiment herein disclosed, but may be advantageously em-

ployed in other types of amplifiers. The volume control operates particularly well when used with a radio frequency amplifier having the grid-plate capacity neutralized. Such neutralization may be effected by connecting a condenser of small capacity between a point in the output transformer and the grid of the tube; the neutralization system is more fully explained in U. S. Patents 1,489,228 and 1,533,858 issued to Hazeltine. The neutralization is particularly valuable in combination with the present invention in that it increases the effectiveness of the amplification control, because such neutralization prevents radio frequency energy from passing through the grid plate capacity of the tube. Thus the relay action of the tube is almost entirely subject to the control by grid bias voltage provided in accordance with this invention.

The volume controlling system may, if desired, be applied to more than one amplifying stage, in the manner disclosed in my co-pending application Serial Number 203,-879, filed July 7, 1927, of which this application is a division.

I claim:

1. In a signaling system, a vacuum tube amplifier having a cathode and a control electrode, a vacuum tube detector coupled to said amplifier, said detector having more than two electrodes including an output electrode, means for maintaining said output electrode normally slightly negative relative to at least part of said amplifier cathode, means for causing said output electrode to become more negative in the presence of an amplified signal, and a direct current connection between said control electrode and said output electrode whereby the amplification of said amplifier is regulated automatically.

2. In a signaling system, a vacuum tube amplifier having a cathode and a control electrode, a three-electrode vacuum tube detector coupled to the output of said amplifier, said detector having an output electrode which is normally slightly negative relative to at least part of said amplifier cathode and which becomes more negative in the presence of an amplified signal, and a direct current connection between said control electrode and said output electrode whereby the amplification of said amplifier is regulated automatically.

3. In a signaling system a vacuum tube amplifier having a cathode and a grid electrode, a three-electrode vacuum tube detector coupled to said amplifier, said detector having a cathode and a plate electrode, which detector cathode is greatly negative relative to said amplifier cathode, and which plate electrode is normally slightly negative relative to said amplifier cathode but becomes more negative in the presence of an amplified signal, and a direct current connection between said grid and said plate whereby the amplification of said amplifier is regulated automatically.

4. In a signaling system, a carrier frequency amplifier comprising a repeating element having a cathode and a control electrode, a three-electrode thermionic detector connected to said carrier frequency amplifier, and an audio-frequency amplifier connected to said detector, said detector having a cathode and a plate electrode which detector cathode is greatly negative relative to said amplifier cathode, and which plate electrode is normally slightly negative relative to said amplifier cathode, but becomes more negative in the presence of an amplified signal, a connection to said audio amplifier, and a direct current connection between said control electrode and said plate, whereby the amplification of said amplifier is regulated automatically.

5. In a signaling system a vacuum tube amplifier having a filament and a grid electrode, a three-electrode vacuum tube detector coupled to said amplifier, said detector having a filament and a plate electrode, which detector filament is connected in a series circuit with said amplifier filament and is substantially negative relative to said amplifier filament, and which plate electrode is normally slightly negative relative to said amplifier filament, but becomes more negative in the presence of an amplified signal, and a direct current connection between said grid and said plate whereby the amplication of said amplifier is regulated automatically.

6. In a signaling system, a carrier frequency amplifier comprising a repeating element having a cathode and a control electrode, a three-electrode thermionic detector and an audio frequency amplifier, said detector having a filament and a plate electrode, which detector filament is connected in a series circuit with said amplifier filament and is substantially negative relative to said amplifier filament, and which plate electrode is normally slightly negative relative to said amplifier filament, but becomes more negative in the presence of an amplified signal, and a direct current connection between said control electrode and said plate whereby the amplification of said amplifier is regulated automatically.

7. A radio receiver comprising a radio frequency amplifier, a detector and an audio frequency amplifier, said amplifiers and detector comprising thermionic space discharge devices each having a cathode, anode and control electrode, the anode of said detector being connected through an impedance to the control electrode of one of said radio frequency amplifying devices for controlling its amplification in accordance with the detector output, said cathodes being connected

in series to a source of heating current, the potential of the cathode of said controlled radio frequency space discharge device being more positive than that of the cathode of said detector whereby said detector may operate with its anode at a negative potential with respect to the cathode of said controlled radio frequency space discharge device.

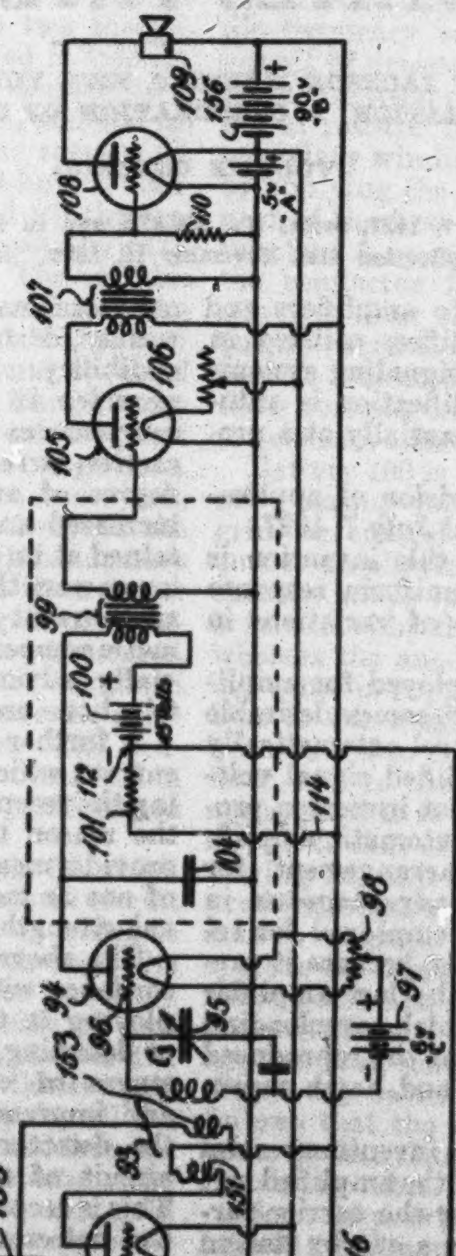
In testimony whereof I affix my signature.
HAROLD A. WHEELER.

DEFENDANT'S EXHIBIT KK

Sept. 27, 1932. H. A. WHEELER 1,879,862

VOLUME CONTROL

Original Filed July 7, 1927



INVENTOR

Harold A. Wheeler,

BY

Pennie, Davis, Marvin and Edmonds

ATTORNEYS

Patented Sept. 27, 1932 1,879,862

UNITED STATES PATENT OFFICE

HAROLD A. WHEELER, OF JACKSON HEIGHTS, NEW YORK, ASSIGNOR TO HAZELTINE CORPORATION, A CORPORATION OF DELAWARE

VOLUME CONTROL

Original application filed July 7, 1927, Serial No. 203,879, and in Great Britain July 3, 1926. Divided and this application filed November 10, 1930. Serial No. 494,580.

This invention relates to amplifiers and more particularly to amplifiers utilized in modulated carrier-current signaling systems wherein the limit of amplification is automatically maintained substantially at a predetermined level.

This application is a division of application Serial No. 203,879, filed July 7, 1927.

The principal object of this invention is to obtain a substantially uniform response from an amplifier in spite of variations in signal intensity.

When amplifiers are employed for amplifying a signal voltage, it becomes desirable for various reasons, to control automatically the amplitude of this amplified signal voltage. To this end the present invention provides means for effecting automatic amplification control. Such an arrangement, for example, is particularly advantageous in radio receivers such as are employed for receiving broadcasting signals, because it prevents the overloading of the last amplifier stage of the receiver, which overloading would result in distortion of the reproduced signal, as well as in loud and harsh reproduction.

Another advantage of the invention resides in uniform reproduction of the amplified signal irrespective of whether the carrier-current signal is received from a nearby station or from a distant station, or from a high power or from a low power station, since it has been found in the case of former rad receivers that when the receiver was reproducing strong signals as from a nearby or high power station, the audibly reproduced signal was very loud, whereas when the signal was received from a distant or low power station, it was relatively weak, with the result that if signals were to be reproduced uniformly from both near and distant stations, and from high power and low power stations, it became necessary to readjust some volume control means in the receiver to compensate for these unequal signals.

It has been a common experience in the use of former radio receivers, that the reproduced signal was not uniform, due to the phenomenon of "fading", whereby the received signal occasionally or periodically became much weaker, or faded almost to the point of inaudibility. Since the present invention provides an amplifier which automatically compensates for inequalities in the received carrier-current, when fading takes place, the degree of amplification is correspondingly increased and the reproduced signal maintained at its former volume so that a listener is unaware that variation of the received carrier current signal is occurring. This automatic compensation for signal fading is especially advantageous in commercial radio-telephone and like systems.

A further advantage is the saving in plate current which is automatically effected during the reception of the powerful signals, for the reason that this invention incidentally provides means for reducing the plate current of one or more amplifying tubes as the signal strength increases.

The above advantages are attained in accordance with the present invention by employing in the signal receiver a rectifying, or detecting, device preceded by one or more stages of carrier frequency amplification and impressing the potential of a point in the detector output circuit upon a control circuit of the carrier frequency amplifier. This is accomplished by connecting a point in the detector output circuit to the control electrode of one or more of the carrier-frequency amplifying tubes. There is included in the detector output circuit the usual audio-frequency transformer for coupling the detector to the audio-frequency amplifier. The volume controlling connection is taken at a point between the primary winding of the transformer and a resistance element which is included in the circuit between the lower end of this primary winding and the detector cathode.

A feature of the invention is a circuit arrangement and means whereby the potential upon the grid of the volume controlling tube is the fall in potential across the resistance in the detector anode circuit. An increase of the signal strength tends to increase the detected current, thereby increasing the negative bias on the control electrode of the vol-

ume controlling tube; which results in decreased amplification.

The drawing illustrates a radio receiver comprising two stages of radio-frequency amplification, a detector and two stages of audio-frequency amplification. The two radio-frequency stages comprise two thermionic amplifiers 90 and 91 coupled in tandem, the output of tube 91 being coupled to a three-electrode detector tube 94, and the input of tube 90 being coupled to an antenna 88. The tubes are coupled in a well-known manner by transformers 89, 92 and 93, the secondary windings of which are tuned by variable condensers C_1, C_2, and C_3. The variable condensers are grounded to eliminate undesirable capacity effects and to enable the condensers to be ganged together and operated by a uni-control arrangement. The primary windings 150 and 151 of transformers 92 and 93 have connected at their low voltage ends, similar windings 152 and 153, the upper ends of which are connected respectively to the grids of tubes 90 and 91 through condensers 154 and 155. The function of these latter condensers is to neutralize the grid-plate capacity of the tubes in a well-known manner, thus preventing the occurrence of sustained oscillations, and otherwise improve the effectiveness of the present invention. The neutralization system is more fully described in U. S. Patents 1,489,228 and 1,533,858, issued to L. A. Hazeltine.

The three-electrode detector tube 94, which is of the C-bias type, has in its anode circuit a battery 100, the positive side of which is connected to the detector anode through the primary winding of an audio-frequency transformer 99. The negative side of battery 100 is connected through a resistor 101 to the positive terminal of a B-battery 156 which is a common anode battery for all the tubes. A suitable negative potential is maintained on the grid 96 of the detector tube by means of a C-battery 97, and this grid potential may be adjusted by a potentiometer 98 connected across the detector cathode. The negative terminal of the C-battery is connected to the secondary winding of transformer 93.

The audio-frequency amplifier comprises thermionic amplifiers 105 and 108 coupled in tandem by an audio-frequency transformer 107, the secondary winding of which has shunted across it a resistance 110, the effect of which is to improve the uniformity of amplification over the voice frequency range. The cathode of amplifier 105 has in its circuit a rheostat 106 for controlling the cathode current. The output of amplifier 108 is connected to a loudspeaker 109, or if desired, to some other type of receiving device such as a meter or telephone system. The first audio-frequency amplifier 105 is coupled to the output of the detector by having its input connected to the secondary winding of transformer 99.

The cathodes of all the tubes are heated by a common "A" battery to which the cathodes are all connected in parallel.

For controlling the amplitude of the radio-frequency voltage applied to the input circuit of detector 94, a conductor 111 is connected between point 112 common to a terminal of resistor 101 and battery 100, and the secondary winding of transformer 89; thereby applying the potential of point 112 to the grid of the first radio-frequency amplifying tube 90. A by-pass condenser 113 connecting the conductor 111 to the filament system serves to filter out and reject any audio-frequency currents present in the circuit including the conductor 111, thereby insuring that these currents have no effect on the grid of the vacuum tube 90.

Battery 100 is in a sense the source of negative biasing voltage applied to the control-grid, or control-electrode of the radio-frequency amplifying tube 90. It will be noted that the anode voltage in the detector circuit is furnished by the two batteries 100 and 156, whereas the anode potential of the remaining tubes is supplied by mattery 156 alone. Due to the magnitude of resistance 101, a suitable value for which will be indicated later, and to the greater total battery voltage applied to the anode of the detector, with respect to that of the other tubes, the current flowing through resistance 101 is sufficient to produce enough potential across the resistance to maintain point 112 negative with respect to the negative terminal of battery 156. Since point 112 is negative with respect to the cathodes and since battery 100 has a voltage less than that of battery 156 (45 volts is shown for battery 100 in the drawing), it follows that the anode potential of the detector is less than that of the anodes of the remaining tubes.

There is provided in the plate circuit of tube 90 a milliammeter 116 for indicating the anode current of that tube. A switch 115 serves to connect the lead 111 to the cathode of tube 90 when desired. The functions of the milliammeter and of the switch will be more fully disclosed later.

In this embodiment, condensers 104 and 113 may be of 0.0005 microfarad and 1 microfarad capacity, respectively; while resistance 101 may have a value of 0.5 megohm. This invention is not limited to the use of these values, but they are given simply to indicate how good results may be obtained.

In the operation of this receiver, a signal received by the antenna 88 is successively amplified through the two radio-frequency amplifier stages. The audio-frequency signals with which the rado-frequency carrier wave is modulated, are then detected in the well-known manner by the grid-bias detect-

or 94. The audio-frequency signals are successively repeated by the audio-amplifying stages comprising thermionic amplifiers 105 and 108, after which they are reproduced as sound by sound reproducer 109.

A detected signal current flowing through resistance 101 causes point 112 of the detector anode circuit to become more negative relative to its cathode, and hence causes the potential of the grid of radio-frequency amplifier 90 to become more negative relative to its cathode, thus decreasing the amplification of this amplifier stage. The stronger the incoming signals become, the more negative becomes the grid of amplifier 90, and the more the amplification is reduced. Conversely, when the signals become weaker the amplification increases. The result of this is that the strength of the signals impressed upon the detector remains nearly uniform for widely different signal strengths.

The automatic volume control not only comprises for fluctuation in the strength of the incoming signals, but also compensates for variations or reduction of the "A" and "B" voltage supply. A drop in the supply voltage, for example, reduces the current through resistance 101, thereby reducing the negative potential on the grid of tube 119 and increasing the amplification. Conversely, an increase of the supply voltage makes the grid of the first radio-frequency amplifier more negative.

In this manner, the radio frequency voltage applied to the input of the rectifier detector is maintained at nearly constant predetermined value, and the volume of the reproduced signal is substantially uniform under all conditions. The degree of volume of the redroduced signal is then determined by adjustment of rheostat 106, which controls the heating current in the filament of the first audio-frequency amplifying tube 105.

In adjusting the receiver it is necessary to determine the correct setting of the detector grid potentiometer 98. This adjustment should be made while there is no signal being recived, as follows: First, the switch 115 is closed, and the normal plate current of the tube 90 is noted on milliammeter 116. Then the switch is opened, thus placing the control circuit in operation. In general, the plate current of vacuum tube 90 will change when the switch is opened, since the grid voltage of this tube is dependent upon the control circuit. By varying the grid voltage of the detector by potentiometer 98 the plate current of tube 90 is then adjusted to the normal value; and the apparatus is ready for operation. Upon receipt of an amplified signal at the detector, the effect of the control circuit is to decrease the plate current through milliammeter 116, thereby reducing the am- is tuned to the signal frequency, a minimum plification of the tube 90. When the receiver is tuned to the signal frequency, a minimum amplification is required, so the condition of resonance is ascertained by a minimum reading of meter 116.

In the event that tubes having an indirectly heated cathode are used instead of those having an electric current heated filament cathode, the same results may be obtained as in the system illustrated in the drawing, if the detector cathode is maintained at the same potential as the cathode of the volume control tube, or tubes.

It is possible to employ in place of the three-electrode detector, a two-electrode rectifier or detector, in the manner set forth in my above mentioned application Serial No. 203,879. An advantage of the three-electrode detector over the two-electrode type is its greater response to weak signals. A particular advantage of the three-electrode detector, as shown combined with an audio frequency transformer, is that the transformer step-up ratio serves to improve the sensitivity of the detector and therefore of the entire receiver.

The volume controlling system may, if desired, be applied to more than one amplifying stage, in the manner disclosed in my co-pending application Serial No. 203,879, filed July 7, 1927, of which this application is a division.

I claim:

In a signaling system, a carrier frequency amplifier comprising a repeating element having a cathode and a control electrode, a detector coupled to said amplifier, said detector having a cathode and an anode, a first source of anode potential common to said repeating element and said detector, the series combination of an output transformer, a second source of direct voltage and a resistance in the output circuit of said detector, the primary winding of said transformer being connected to said detector anode, said resistance being connected to the positive terminal of said first source of anode potential, and a connection from a point between said resistance and said second source of potential to said control electrode whereby the amplification of said amplifier is regulated automatically.

In testimony whereof I affix my signature.

HAROLD A. WHEELER.

4

CERTIFICATE OF CORRECTION.

Patent No. 1,879,862. September 27, 1932.

HAROLD A. WHEELER.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, line 93, for the word "mattery" read battery; and line 128, for the misspelled compound word "rado-frequency" read radio-frequency; page 3, line 23, for "comprises" read compensates; line 40, for the misspelled word "redroduced" read reproduced; line 48, for "recived" read received; and line 64, strike out the words "is tuned to the signal frequency, a minimum"; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 29th day of November, A. D. 1932.

M. J. Moore,
Acting Commissioner of Patents.

(Seal)

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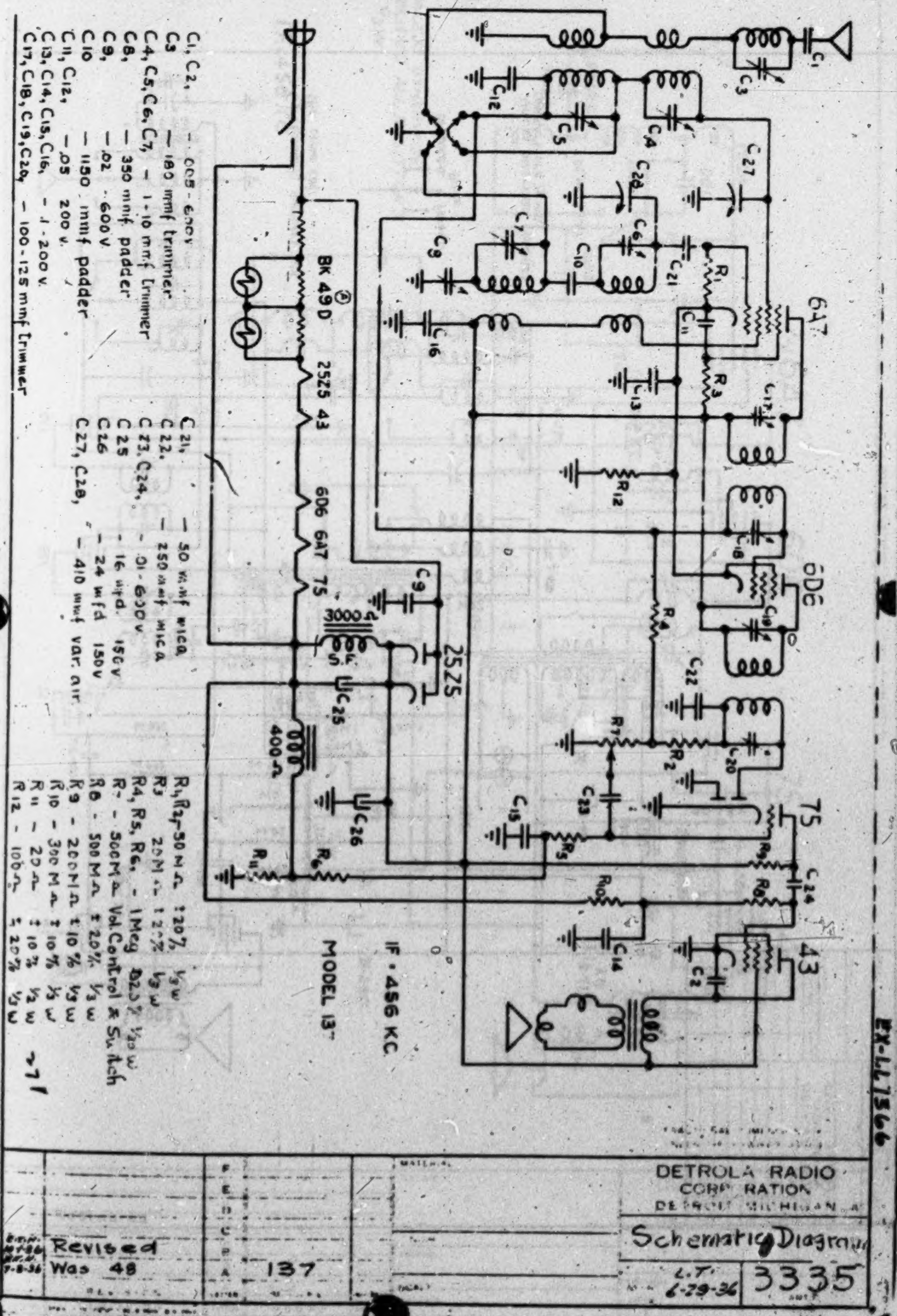
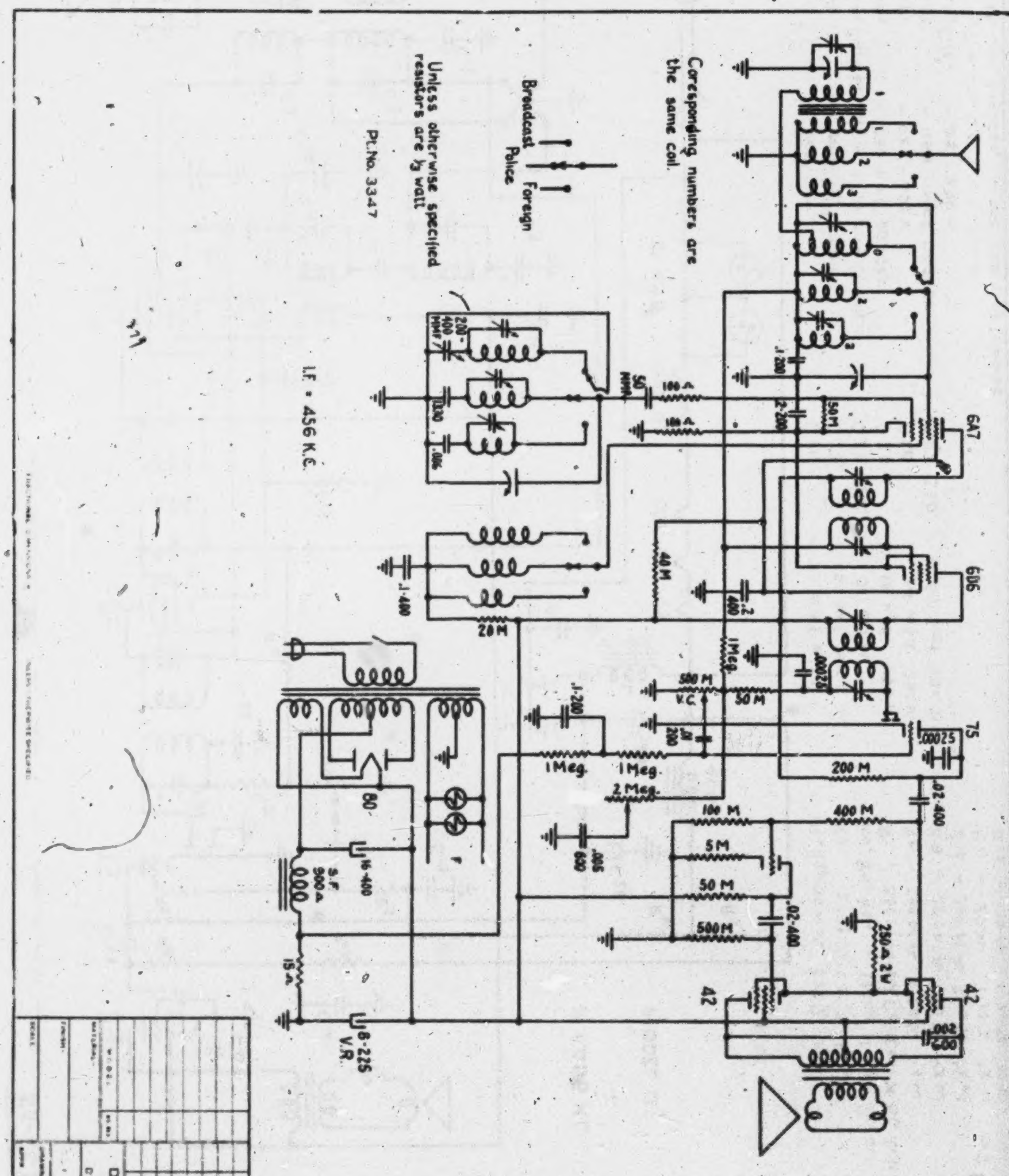
DEFENDANT'S EXHIBIT LL

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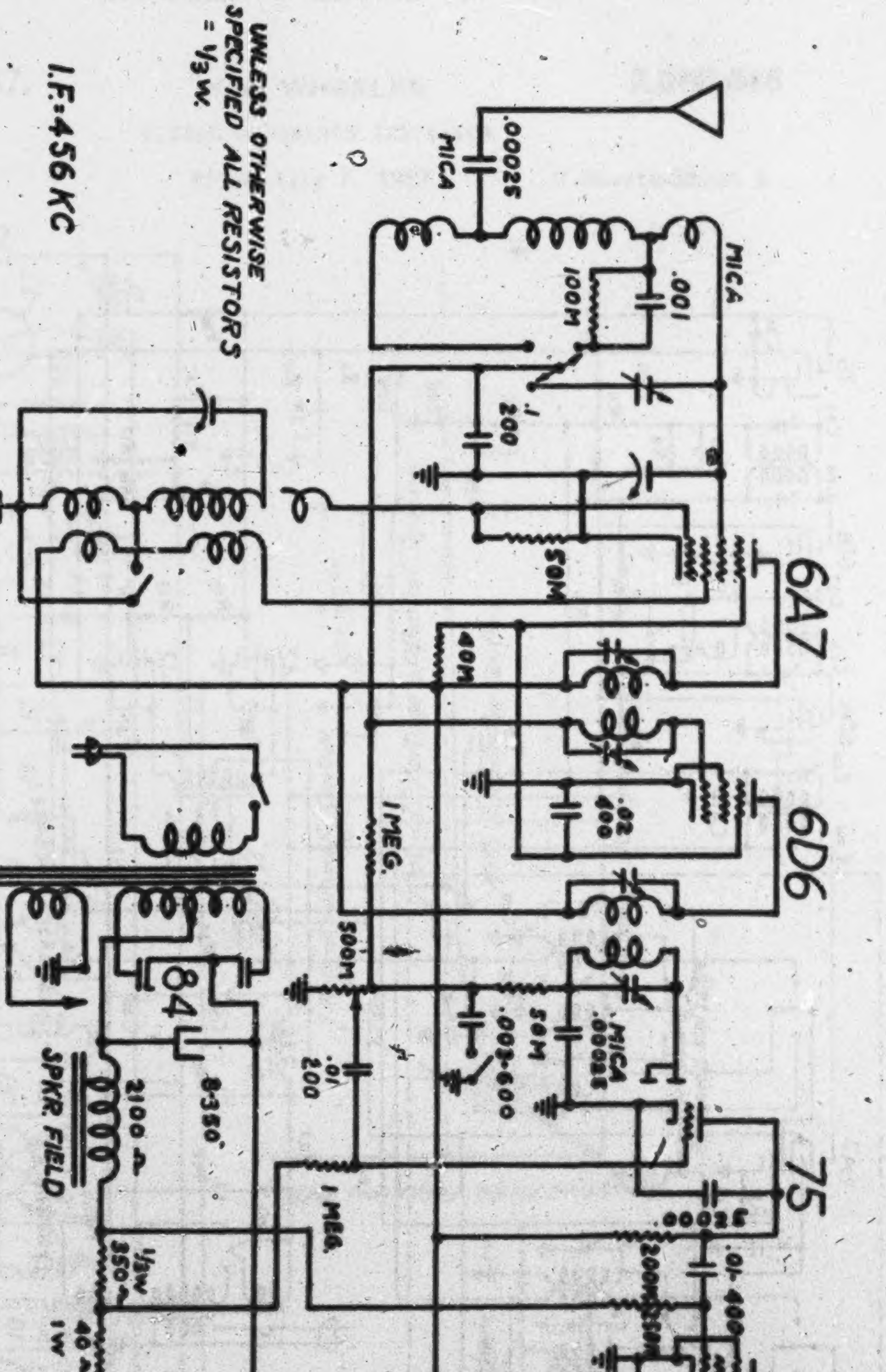

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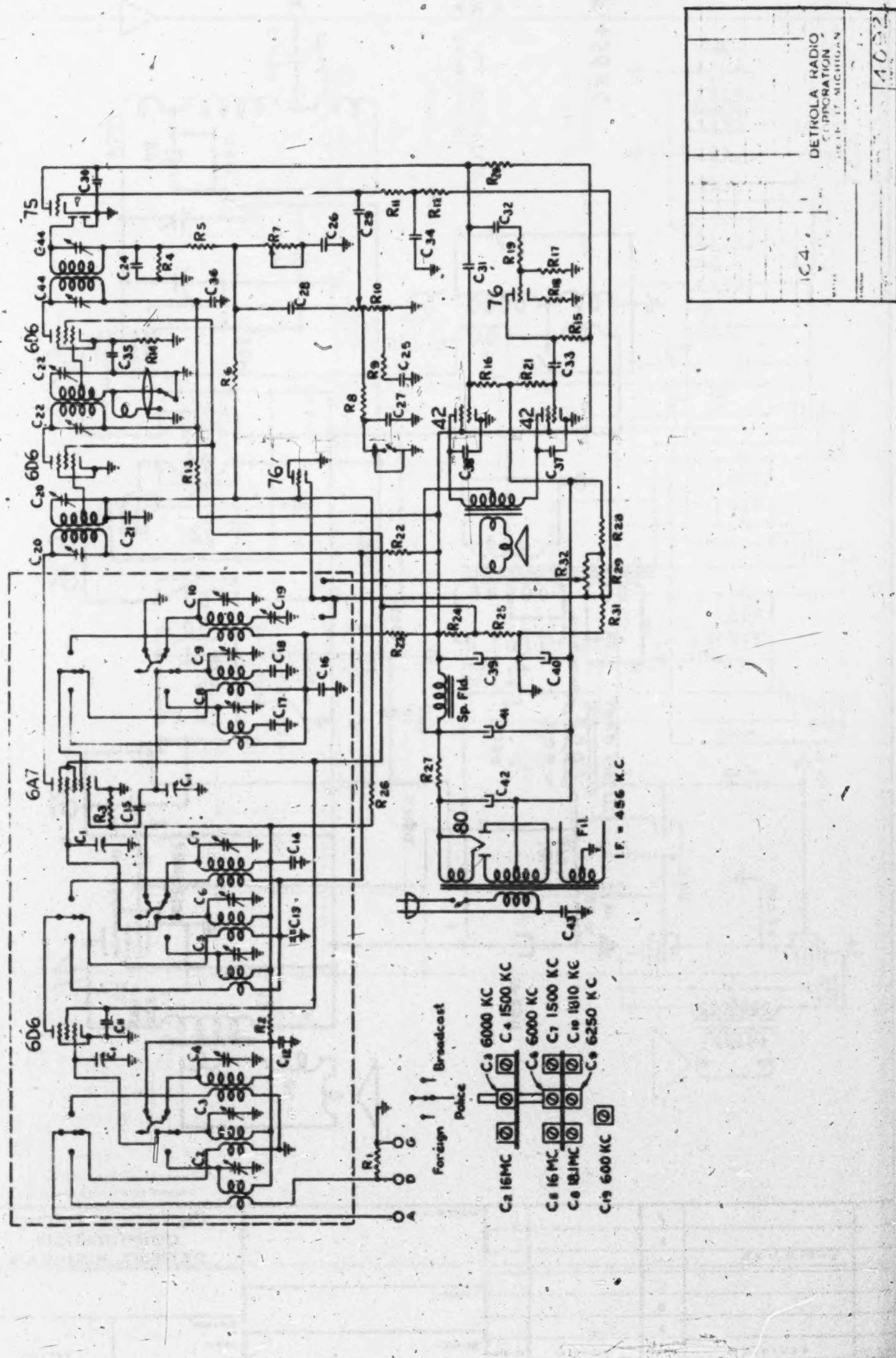
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C10 1810 KC
C9 6250 KC
C19 600 KC
DETROLA RADIO
CORPORATION

DEFENDANT'S EXHIBIT MM

May 18, 1937. **H. A. WHEELER** **2,080,646**

VISUAL RESONANCE INDICATOR

Filed July 7, 1927 2 Sheets-Sheet 1

Fig. 1.

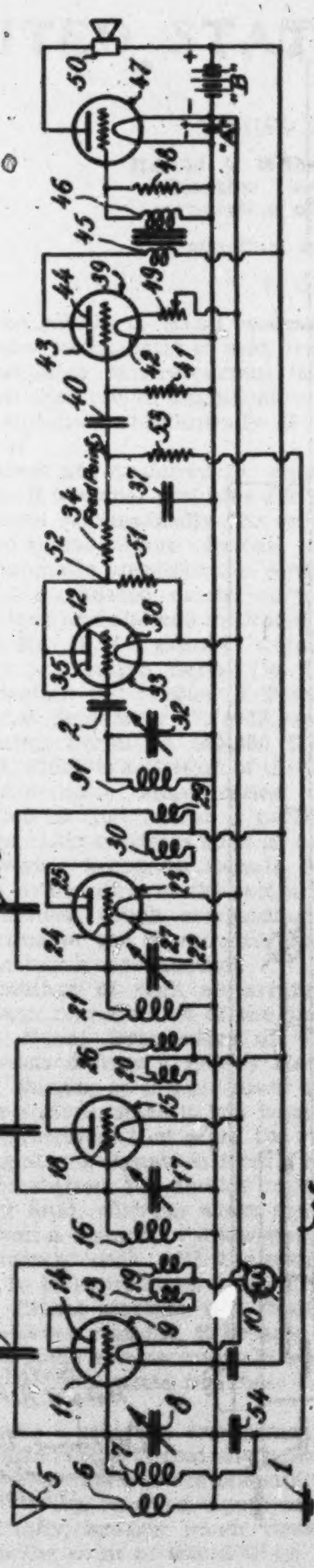


Fig. 2.

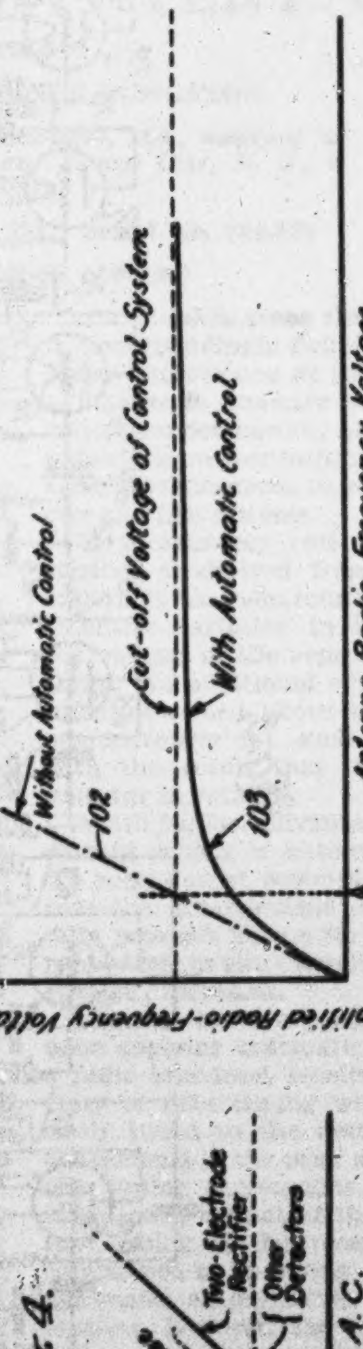
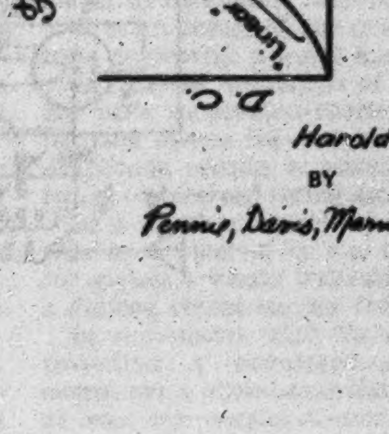


Fig. 4.



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Pennie, Davis, Marvin & Edmonds
ATTORNEYS

May 18, 1937. H. A. WHEELER 2,080,646

VISUAL RESONANCE INDICATOR

Filed July 7, 1927 2 Sheets-Sheet 2

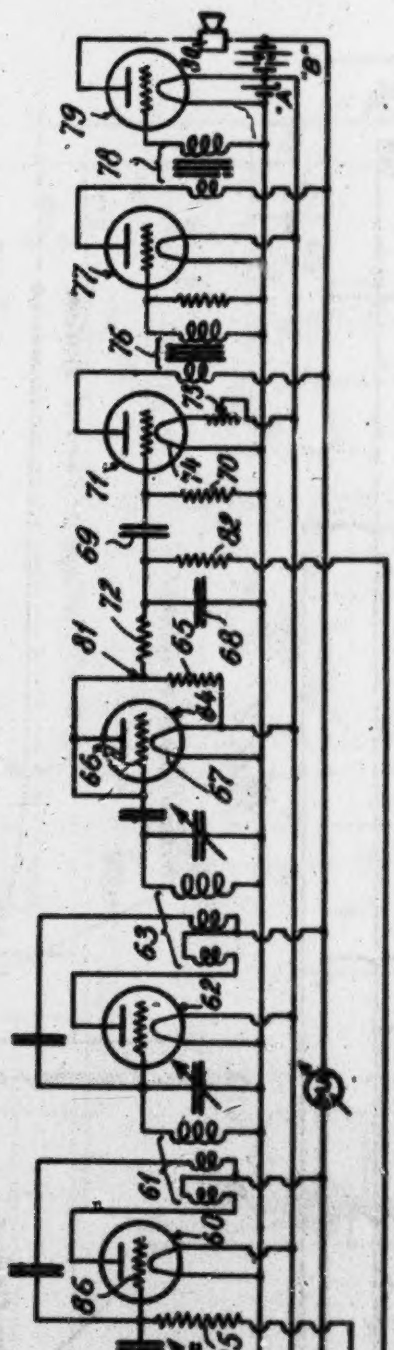

Fig. 3.

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Patented May 18, 1937

2,080,646

UNITED STATES PATENT OFFICE

2,080,646

VISUAL RESONANCE INDICATOR

Harold A. Wheeler, Baltimore, Md., assignor to Hazeltine Corporation, Jersey City, N. J., a corporation of Delaware

Application July 7, 1927, Serial No. 203,879

14 Claims. (Cl. 250—20)

This invention relates to visual resonance indicators and more particularly to said indicators utilized in modulated carrier-current signaling systems wherein the limit of amplification is automatically maintained substantially at a predetermined level.

When amplifiers are employed for amplifying a signal voltage it becomes desirable for various reasons to control automatically the amplitude of this amplified signal voltage. Certain embodiments of an automatic amplification control arrangement in a modulated carrier-current receiver are described and claimed in United States Letters Patent Re. 19,744, granted October 29, 1935, upon my application Serial No. 745,651, being an application for reissue of Patent No. 1,879,863, granted September 27, 1932, upon my original application Serial No. 495,386, filed November 13, 1930, which is a division of the present application. Automatic amplification control such as described in that patent is particularly advantageous in radio receivers such as are employed for receiving broadcast signals, because it prevents the overloading of the last amplifier stage of the receiver, which overloading would result in distortion of the reproduced signal, as well as loud and harsh reproduction.

Another advantage of such an arrangement resides in uniform reproduction of the amplified carrier-current signal irrespective of whether the signal is received from a nearby station or from a distant station, or a high-power station, or a low-power station, since it has been found in former radio receivers that when the receiver was reproducing strong signals as from a nearby, or a high-power station, the audibly reproduced signal was very loud, whereas when the signal was received from a distant, or a low-power station, it was relatively weak, with the result that if signals were to be reproduced uniformly from both near and distant stations, and from high-power and low-power stations, it became necessary to readjust some volume controlling means in the receiver to compensate for these unequal signals.

It has also been a common experience in the use of former radio receivers that the reproduced signal was not uniform due to the phenomenon of "fading", whereby the received signal occasionally, or periodically, became much weaker, or faded almost to the point of inaudibility. Since an arrangement as disclosed in the above-mentioned patent provides an amplifier which automatically compensates for inequalities in the received carrier-current signal strength, when "fading" takes place the degree of amplification is correspondingly increased and the reproduced signal maintained at its former volume, so that a listener is unaware that variation of the received carrier-current signal is occurring. This automatic compensation for signal fading is especially advantageous in commercial radio telephony and like systems.

In present-day receivers in which operating current is derived from the municipal power system, it has been found that when there is considerable variation in the line voltage supply, the volume of the reproduced signal is not uniform. An additional advantage of the arrangement described above is that of automatically compensating for such line voltage variations with the result that the reproduced signal is uniform in volume.

A still further advantage is the saving in plate current which is automatically effected during the reception of powerful signals, for the reason that the arrangement described above incidentally provides means for reducing the plate current of one or more amplifying tubes as the signal strength increases.

There is, however, one disadvantage attendant upon applying automatic amplification control to a radio broadcast receiver and that is the difficulty of determining when the receiver is precisely tuned to the desired signal. In the arrangements of the prior art, the condition of precise tuning corresponds critically to the maximum sound output of the receiver so that accurate tuning of the receiver can readily be accomplished by observing the sound output. With automatic amplification control applied to the receiver, however, the sound output varies only within a relatively narrow range so that it is impracticable, or at least difficult, to tune the receiver by its audible response.

It is an object of the present invention, therefore, to provide a novel and improved means for obtaining an indication of the condition of tuning of a modulated-carrier signal receiver embodying means for maintaining its signal output amplitude within a narrow range for a wide range of received signal amplitudes.

It is another object of the invention to provide in a receiver of the type described, means for giving a visual indication of resonance with a desired signal-carrier frequency.

In accordance with the preferred form of the invention, a modulated-carrier signal receiver comprises a signal-translating channel including at least one carrier-frequency vacuum-tube am-

plifier having a tunable signal-selecting circuit coupled to its input circuit and a sound-reproducing means coupled to its output circuit. The receiver includes also means responsive to variations of received signal intensity for controlling the amplification, and thus the space current, of such tube or tubes inversely in accordance with amplitude of the received signal carrier to maintain the sound output of the receiver within a relatively narrow range for a wide range of received signal intensities, whereby audible indication of resonance with the desired signal is difficult or impracticable. In order to obtain an indication of the accuracy of tuning of the receiver to a desired signal, there is provided a visual resonance indicating means connected to be responsive to the output of the amplifier or signal-translating channel. It will be apparent that, assuming all signals to be precisely tuned in, the response of the visual resonance indicator will be a measure of the amplitude of the received signal carrier, that is, the resonance indicator acts also as an indicator of relative signal strength.

Fig. 1 is a circuit diagram of a complete radio receiver which includes the present invention, and consists of a three-stage radio-frequency amplifier followed by a rectifier, a two-stage audio-frequency amplifier, and a loud speaker, or other suitable indicating device.

Fig. 2 shows curves disclosing the relation between the radio-frequency antenna voltage and the radio-frequency amplified voltage, with and without the application of automatic amplification control.

Fig. 3 shows a circuit diagram of a second embodiment of the invention in which there is disclosed a three-stage tuned radio-frequency amplifier, a rectifier, and a three-stage audio-frequency amplifier.

Fig. 4 shows graphically a comparison between the performance of the two-electrode valve or rectifier, and of the three-electrode detector.

Referring in detail to Fig. 1, there is shown an antenna 5 connected to ground 1 thru the primary winding 6 of a radio-frequency transformer, the secondary winding 7 of which, tuned by a variable condenser 8, is connected at one point to the filament 27 of the vacuum tube 9 in the first radio-frequency amplifying stage and at another point to the grid 11 of this vacuum tube. The output circuit of this vacuum tube extends from the filament system, thru a high-voltage battery "B", a milliammeter 10, primary winding 12 of a second radio-frequency transformer to the anode or plate 14 of this vacuum tube. In order to neutralize the inherent capacity between the grid 11 and the plate 14, and thereby to prevent oscillations, a neutralizing winding 13, electromagnetically coupled to winding 12, and a neutralizing condenser 3 are employed in the manner described in the U. S. patents to Hazeltine Nos. 1,489,228 and 1,533,858.

A second stage of radio-frequency amplification including the vacuum tube 15 neutralized by cooperation of coil 26 and condenser 4, like the first stage, comprises the secondary winding 16 of the last-mentioned radio-frequency transformer tuned by a variable condenser 17 connected between the filament system of the vacuum tube 15 and the grid 18 thereof. The output circuit of this vacuum tube also includes the high-voltage battery "B" and a primary winding 20 of a second radio-frequency transformer, while the secondary winding 21 of this transformer tuned by a variable condenser 22 is included in the input circuit of a third stage of radio-frequency amplification which includes vacuum tube 23. The inherent capacity effective between the electrodes 24 and 25 is neutralized by a network including the neutralizing condenser 28 and the neutralizing winding 29 as described in the mentioned patents. The output circuit of the vacuum tube 23 includes the primary winding 30 of a third radio-frequency transformer and the high-voltage battery "B". The secondary winding 31 of this last-mentioned transformer, tuned by a variable condenser 32, is connected in the input circuit of a rectifier 33 which input circuit includes the fixed condenser 2. The rectifier employed is a two-electrode rectifier which may be of the type commonly known in the art as a "Fleming" valve, or it may consist of an equivalent such as a three-electrode vacuum tube, as shown, having its grid 12 and its plate or anode 35 directly connected together to comprise in effect a single anode.

In the absence of the control circuit 36, to be described, the signal-translating channel comprising the three-stage tuned radio-frequency amplifier, including the vacuum tubes 9, 15, and 23 and rectifier 33, functions in a manner well known in the art to amplify selectively the incoming modulated-carrier signals of any carrier amplitude within a wide range which are intercepted on the antenna 5. The output circuit of the rectifier 33 includes what may be termed a "rejector" circuit for stopping radio-frequency currents which have passed thru the rectifier, and consists of a network including a resistance 34 and a by-pass condenser 37 connected between the anode 35 and the filament 38 of the rectifier. The output circuit of the rectifier is coupled to the input circuit of an audio-frequency amplifying vacuum tube 39 thru an audio-frequency-pass filter including a fixed condenser 40 and an impedance resistance 41 connected between the filament 42 and the grid 43 of this vacuum tube. As appears from the constants hereinafter given, the characteristics of the filter are such that it passes the audio-frequency component to the input circuit of the audio- or modulation-frequency amplifier, while preventing the uni-directional component from being impressed upon the input circuit thereof. The output circuit of this amplifier is connected between the filament 42 and plate 44 thru the high-voltage battery "B" and the primary winding 45 of an audio-frequency transformer the secondary winding 46 of which is connected in the input circuit of a second audio-frequency tube 47, while a resistance 48 connected across the winding 46 serves to give the audio amplifier substantially uniform amplification over the desired frequency range. Instead of employing resistance 48, a closed copper band of suitable size may be placed around the transformer winding so as to be electromagnetically coupled thereto. A loud speaker or other reproducing device 50, or if required, a coupling device for a telephone system, is connected in the output circuit of the last audio-frequency amplifying tube 47. It is presumed that adequate precautions against undesired electromagnetic coupling between the various radio-frequency coupling transformers are included in all of the arrangements herein disclosed.

The degree of amplification effected in the radio-frequency amplifying stages is automatically controlled by a biasing potential obtained by

rectifying the modulated signal carrier in a two-electrode rectifier 33, having a resistance 51, connected between the filament 38 and the anode or output electrode 35 of the rectifier, thru which the pulsating rectified or converted current flows, thereby developing a negative voltage at terminal 52. This negative voltage is applied over conductor 36 thru the resistance 53 and the secondary winding 7 of the first radio-frequency transformer to grid 11 of the first radio-frequency amplifier stage. Resistance 53, together with blocking condenser 54, is effective in producing a time constant predetermined to filter out and reject voltage fluctuations at frequencies of modulation of the selected and amplified signal, that is, any audio-frequency voltages which otherwise might be applied from conductor 36 to the grid 11.

To complete the description of the system illustrated in Fig. 1 certain design data or constants are given herewith. It should be understood, however, that these, as well as other constants appearing in the present specification, are mentioned merely by way of example in describing certain specific embodiments which in practice have proved satisfactory, and are not intended to suggest any specific limitations as to the scope of this invention. Accordingly, fixed condenser 2 may be of 0.0005 microfarads; 37 of 0.0001 microfarads; 54 of 0.01 microfarads; 48 of 0.005 microfarads; resistance 51 of 1 megohm; 34 of 1 megohm; and 41 and 53 of 2 megohms each. The tubes may be assumed to be all of the well-known 201A type.

In the operation of the receiver shown in Fig. 1, a modulated-carrier signal intercepted on the antenna 5 is selected and successively amplified thru the neutralized, tuned radio-frequency amplifier stages indicated by the vacuum tubes 9, 15 and 23 connected in cascade. The selected and amplified signal is then rectified by the rectifier 33, and the rectified pulsating current is successively amplified by the audio amplifying stages including vacuum tubes 39 and 47, after which it may be reproduced as sound by the loud speaker 50. The high resistance 51 connected between the filament 38 and the anode 35 of the rectifier, through which a small space current flows in the absence of signal output from the radio-frequency amplifier, maintains the anode normally negative relative to at least part of the filament of the rectifier. Since all the filaments are connected in parallel, the rectifier filament is maintained at substantially the same potential as the filament 27 of the first radio-frequency amplifier tube 9. Therefore, the resistance 51 is connected effectively between the rectifier anode 35 and the amplifier filament 27, and thereby determines the normal negative potential of the rectifier anode relative to at least part of the amplifier filament or cathode. When the rectified or converted signal voltage across resistance 51 increases with signal output beyond a predetermined value, there is developed at the anode terminal 52 sufficient increase of negative biasing voltage which in turn is impressed, thru the conductor 36, upon the grid or control electrode 11 of the vacuum tube 9, to reduce the amplification of this tube. Conversely, it will be apparent that as the magnitude of the rectified current flowing thru resistance 51 decreases with decreasing signal strength, the direct voltage at terminal 52 becomes less negative, and the negative biasing voltage impressed upon the grid 11 also diminishes so that the vacuum tube 9 effects an increased degree of amplification. In this manner, the radio-frequency voltage applied to the input of the rectifier is maintained within a relatively narrow range, and the volume of the reproduced signal is substantially uniform for a wide range of received signal intensities. The degree of volume of the reproduced signal is then determined by adjustment of rheostat 40 which controls the heating current in the filament 42 of the first audio-frequency amplifying tube 39. In the above operation it is noted that the two-electrode or diode rectifier 33 functions as the detector and also effects rectification of the radio-frequency carrier current to control amplification in the first radio-frequency stage of the receiver. The audio-frequency component of the detector output is transferred to the input circuit of the audio-frequency amplifier for further amplification. The neutralization of the grid-plate capacity of the radio-frequency amplifying tubes is, in the system disclosed, particularly valuable in that it allows an increase in the effectiveness of the amplification control, because such neutralization prevents radio-frequency energy from passing thru the grid-plate capacity of the tubes. Thus the relay action of the tubes is almost entirely subject to the control by grid bias voltage.

The time required for operation of the control system would ordinarily be determined by the lowest audio-frequency modulation which must be reproduced. Fading, for example, might be considered a form of modulation; the frequency of the rise and fall of signals due to fading being the frequency of modulation. If this frequency of modulation be increased sufficiently, the effect will be audio-frequency modulation. It will thus be seen that if the automatic control be allowed to respond too quickly, it will tend to smooth out the desired modulation of the signals at the lower audio frequencies. Hence, a time constant of operation is chosen which will be greater than the period of the audio frequencies which the system is intended to amplify. This time constant of the control circuit is equal to the product of the series resistance and the shunt capacitance of the grid bias circuit, represented in Fig. 1 by resistance 53 between conductor 36 and the anode terminal 52, in the direct-current connection back to the grid 11, and condenser 54 connected between the amplifier filament 27 and a point or conductor 36. Since the time constant can always be reduced to a value equal to the period of the lowest modulation frequency, it may readily be set to meet the requirements of nearly any special case which may arise. For example, a value of two million ohms resistance and of 0.1 microfarad capacitance gives a time constant of one-fifth of a second, which does not appreciably affect the modulation of frequencies above five cycles. While this constant is greater than required from the point of view of satisfactory audio-frequency quality in the reproduction of music, there appears to be no need for more rapid control under the conditions usually encountered. Even with a time constant of the order of one-fifth of a second, however, the time lag of the automatic amplification control is so small as to allow it to follow closely variations in the signal output intensity of the receiver as it is tuned in the vicinity of resonance, that is, the control is substantially inertialess, so that audible indication of resonance is impracticable. The use in this connection of con-

densers of large capacitance, such as one-tenth microfarad, likewise introduces another convenience in that the condensers may also serve to by-pass radio frequencies in order to prevent undesired coupling between the detector circuit and the first radio-frequency amplifying tube because of some impedance common to those two portions of the apparatus.

For a better understanding of the system described above, reference is made to Fig. 2 from which it will be appreciated that, in a system similar to that illustrated in Fig. 1 but in which no means for automatically limiting the degree of amplification is included, the amplified radio-frequency voltage is proportional to the radio-frequency antenna voltage, as indicated by curve 102. When, however, automatic amplification control is applied to such an amplifier, the relation between the radio-frequency antenna voltage and the amplified radio-frequency voltage is indicated by curve 103 from which it will be seen that when at least a certain predetermined radio-frequency antenna voltage is present, (herein referred to as the "threshold antenna voltage") the amplified radio-frequency voltage approaches—but is always less than—another certain predetermined voltage value (herein referred to as the "cut-off voltage").

As stated above, in the case of a modulated-carrier signal receiver having automatic amplification control as just described, it is impracticable to attempt to tune the receiver accurately by the audible response, since the sound output varies only within relatively narrow limits which are not readily detectable by the ear. In order to provide a visual indication of resonance, there is provided a visual indicating device connected to be responsive to the output of the signal-translating channel. As shown, this device comprises a milliammeter 10 connected in the anode circuit of the amplifying vacuum tube 9. The effect of the control circuit is to vary the amplification in the tube 9, and incidentally to vary the plate current through the milliammeter 10 inversely in accordance with variations of received signal intensity. When the receiver is precisely tuned to the signal frequency, the amplitude of the signal voltage developed across tuned circuit 7, 8 and impressed upon the control grid of the tube 9 is a maximum. Under these conditions, a minimum amplification in this tube is required, the plate current of tube 9 reaches a minimum value, and the milliammeter 10 so indicates. Thus the milliammeter 10 visually indicates the degree of amplification and, thus, the condition of resonance with the desired signal-carrier frequency. Because of the fact that the automatic amplification control maintains the variations in the input to the detector 33, and thus the variations of the space current of the tube 9, within a relatively narrow range, the range of the milliammeter 10 may be correspondingly small. When the receiver has been precisely tuned, as just described, it is in condition to provide a maximum range of control of amplification to compensate for variations in the signal input intensity due to fading or other causes. Since, under any given operating conditions, the milliammeter 10 indicates the amplitude of the signal voltage impressed upon the control grid of the tube 9, it is also effective to indicate relative signal strength as between different signals, assuming that in each case the receiver is precisely tuned to the particular signal being received.

The modification illustrated in Fig. 3 includes antenna 56, connected by means of a transformer 57 to a neutralized three-stage tuned radio-frequency cascade amplifier including the vacuum tubes 58, 60 and 62 coupled by transformers 59 and 61. The last stage of the amplifier is connected by a transformer 63 to a two-electrode rectifier 64 of the type already described, the output circuit of which, including the resistance 65, is connected between the anode 66 and filament 67 of the rectifier, as previously explained. Resistance 72 and condenser 68 associated with this output circuit, constitute a "rejector" network which filters out the radio-frequency current component in the output circuit of the rectifier 64, while the network including condenser 69 and resistance 70 constitutes an audio-frequency-pass filter for coupling the output circuit of the rectifier to the input circuit of the audio-frequency amplifier which includes vacuum tube 71. Rheostat 73 controls the heating current supplied to the filament 74 of this vacuum tube, and thereby permits a manual adjustment of the volume of the reproduced signal desired by the listener. Audio-frequency transformer 76, which is preferably of a low ratio of transformation, couples the output circuit of vacuum tube 71 to a second audio-frequency amplifying tube 77. This last vacuum tube in turn is coupled by a second audio-frequency transformer 78 to a third audio-frequency amplifying tube 79 in the output circuit of which there is included a loud speaker 80.

In this arrangement automatic amplification control is effected in the same manner as in Fig. 1, except that in this instance the radio-frequency voltage of the signals intercepted by the antenna 56 is successively amplified by three neutralized tuned radio-frequency amplifying stages including the vacuum tubes 58, 60 and 62, the amplification of two of which is controlled in accordance with received signal intensities. The amplified radio-frequency current is rectified by the rectifying valve 64 and successively amplified at audio-frequency by the vacuum tubes 71, 77 and 79. The rectified current in the output circuit of the rectifier flows thru the resistance 65, and thereby develops a negative voltage at the terminal 81, which voltage is applied thru the resistances 72, 82, 83 and 85 to the grids 84 and 86 of the radio-frequency amplifying tubes 58 and 60. By thus simultaneously controlling the degree of amplification of two successive radio-frequency amplifying stages, a greatly increased uniformity of regulation is attained. Resistance 82 and the condenser 87 constitute an audio-frequency-stop filter, so that substantially only direct-voltage is impressed upon the grids 84 and 86. It will be understood that the voltage developed at terminal 81 is a function of the amplified radio-frequency voltage delivered to the input circuit of the rectifier by the radio-frequency amplifying tubes 58, 60 and 62, and therefore, as the negative voltabe at terminal 81 tends to increase with the increasing signal, the resulting increase of biasing voltage impressed upon the grids of the tubes 58 and 60 limits the degree of amplification effected in the radio-frequency stages including those tubes. As in the system of Fig. 1, the milliammeter MA gives a visual indication of resonance of the receiver to a received signal and a measure of relative signal-strength as between different signals.

In this arrangement the constants for the various resistances and condensers may, for ex-

ample, be the same as those for the corresponding elements in Fig. 1. In addition the grid resistances 83 and 85 may have a value of 2 megohms each; and the grid condensers connected at the junctions of these resistances and the grid electrodes 84 and 86 may each be of 0.001 microfarad capacity.

There are advantages attending the use of the two-electrode rectifier circuit typified by Figs. 1 and 3, which may not be apparent from the foregoing discussion. It is impossible to overload this type of rectifier, and the rectified output voltage is directly proportional to the applied alternating signal voltage when this voltage is large, say over two volts. The control system in the circuits of the figures referred to requires a large operating voltage, say ten volts, so that the latter condition of large signal voltage is realized. No such simple relationship is possible in a three-electrode detector, whose rectified output never exceeds a limiting upper value, and is never proportional to the applied voltage, except over a very small range of voltages. This distinction will be seen from Fig. 4 where the abscissae "A. C." represent the alternating signal voltages, whereas the ordinates "D. C." represent the rectified output voltages. It is well known that the linear curve is much more desirable when minimum distortion of a modulated signal is desired, and it will be observed from Fig. 4 that the preferred type of curve is obtained from the two-electrode rectifier. A further advantage of the "linear" type of detector with automatic amplification control connection and a visual resonance indicator in the anode circuit of the amplifier whose grid bias is being automatically controlled, lies in the fact that the visual resonance indicator will give an indication which is proportionate to the received signal intensity. This follows from the fact that the negative grid bias on the amplifier is directly proportional to the strength of the signal, and hence the anode current bears a similar relation to the signal.

If a three-electrode detector were used in an automatic amplification control system, and the rectified output voltage would be approximately proportional to the square of the applied voltage, i. e., to the power associated with the applied voltage. For this reason the rectified voltage would increase with the carrier wave modulation. Therefore, if such a detector were so used, the total power from the radio-frequency amplifier would be maintained at a substantially constant level, the amplitude of the carrier wave being decreased in the presence of modulation. It is desirable to maintain the carrier wave at a constant amplitude at the output of the amplifier, and this is accomplished by the two-electrode rectifier as shown in Figs. 1 and 3. The control system maintains constant the average signal amplitude which is equal to the carrier wave amplitude and independent of the degree of modulation.

It will be observed that in a system employing a two-electrode rectifier such as represented by tube 33 of Fig. 1, and 64 of Fig. 3, the control bias voltage is independent of the "B" or anode battery voltage. Since the rectifier is not an amplifier, is not critical, and requires neither anode nor biasing battery, no adjusting devices are required. This is not the case in three-electrode detector circuits, in which an adjustment must be made as by a potentiometer to accommodate the control bias to any particular combination of tubes and "B" voltage.

In the foregoing description, tuned radio-frequency receivers of the neutralized type have been referred to. It should be pointed out, however, that the present invention may be employed effectively in connection with any radio receivers in wired radio and space radio systems, and that it has been found especially applicable to receivers of the super-heterodyne type. For these reasons the present disclosure of typical embodiments of the invention should not be construed as a limitation, but merely as illustrative of the principles of the invention, the scope of which is defined in the appended claims.

What is claimed is:

1. A carrier-frequency signal receiver normally responsive to signals having a wide range of input intensities, comprising means for tuning the receiver to resonance with a desired signal, substantially inertialess electrical control means responsive to received signal intensity for automatically maintaining the signal output intensity of the receiver within a relatively narrow range, and visual resonance indicating means responsive to variations of said output intensity.

2. A carrier-frequency signal receiver normally responsive to signals having a wide range of input intensities, comprising a signal translating channel including a vacuum tube having an anode circuit, means for automatically maintaining the signal output of said channel within a relatively narrow range comprising means responsive to variations of the received signal intensity for varying the space current of said tube, and means responsive to said space current for visually indicating variations of received signal intensity.

3. A carrier-frequency signal receiver normally responsive to signals having a wide range of input intensities, comprising an automatic control electrically linking portions of said receiver for maintaining the signal output intensities of said system within a relatively narrow range, and visual indicating means of small range responsive to said output intensity for automatically indicating said input intensities.

4. A modulated-carrier signal receiver normally subject to undesired variations of signal input intensity, comprising means for tuning the receiver to a desired signal, means for producing an audible response received signal-carrier to modulations, a substantially inertialess automatic control electrically linking portions of said receiver for maintaining said audible response within a relatively narrow range for a wide range of signal input intensity variation, and means for visually indicating when the tuning means is in proper adjustment for automatic control of said audible response over the maximum range of variation of said desired signal input intensity.

5. In a modulated-carrier signal receiver including selective means tunable to a desired signal, the method of tuning the receiver to resonance with said desired signal which comprises amplifying said signal at a carrier frequency, producing an audible response to the amplified signal, automatically controlling the amplification to maintain the audible response within a relatively narrow range for a wide range of signal input intensities with a time lag of automatic control so small that audible indication of resonance is impracticable, and visually indicating the relative degree of amplification and thereby the tuning adjustment at which said desired signal is received with optimum selectivity.

6. A carrier-frequency signal receiver including a vacuum-tube amplifier tunable to resonance with a signal frequency, means for automatically

maintaining the amplified signal intensity within a narrow range for a wide range of received signal intensities, whereby audible indication of resonance is impracticable, and means for visual indication of resonance comprising a device responsive to variation in the unidirectional space current of one or more of said amplifier tubes.

7. A modulated-carrier signal receiver comprising tuning means for tuning the receiver to a desired signal, means for producing, in response to modulations in the received signal, an audible output varying within a narrow range for a wide range of received signal intensities, and visual means for indicating when the tuning means is in proper adjustment for control of said audible output by said second means over the maximum range of said received signal intensities.

8. A modulated-carrier signal receiver comprising a vacuum tube having an anode circuit, a cathode and a grid, a tunable circuit connected between the cathode and grid, whereby the receiver may be adjusted to respond to a desired signal, sound reproducing means, means for translating the signal from said tube to said sound reproducing means, means for controlling the bias potential on said grid in response to the intensity of the received signal, thereby to maintain the sound output from said sound reproducing means within a narrow range for a wide range of received signal intensities, and means responsive to the magnitude of the unidirectional space current flowing in said anode circuit for visually indicating the condition of adjustment of said tunable circuit with reference to the carrier frequency of the received signal.

9. A carrier-frequency signal receiver including a vacuum-tube amplifier, means for adjustably tuning the receiver to resonance with a desired signal, means for automatically maintaining the amplified signal intensity within a narrow range for a wide range of received signal intensities by control of the space current of one or more of the tubes of said amplifier, whereby the usual audible indication of resonance is impracticable, and a meter connected in circuit with the space current circuit of one or more of the automatically controlled tubes of said amplifier for visual indication of resonance.

10. A modulated-carrier signal receiver including a vacuum-tube amplifier, means for tuning the receiver to resonance with the carrier frequency of a desired signal, a rectifier coupled to the output of said amplifier for detecting the modulations, means for automatically maintaining the modulation signal intensity within a narrow range for a wide range of received signal intensities by automatic control of the space current of said amplifier, and resonance indicating means directly responsive to changes in the space current of said vacuum-tube amplifier.

11. A carrier-frequency signal receiver normally responsive to signals having a wide range of signal input intensities, including a signal-translating channel, means for tuning the receiver to resonance with a desired signal, means responsive to received signal intensity for maintaining the signal output intensity of said channel within a relatively narrow range, and visual resonance indicating means connected to respond to the output of said channel.

12. A carrier-frequency signal receiver normally responsive to signals having a wide range of signal input intensities, comprising a vacuum-tube amplifier, means for tuning said receiver to resonance with a desired signal, means responsive to received signal intensity for maintaining the signal output intensity of said amplifier within a relatively narrow range, and visual resonance indicating means connected to respond to the vacuum-tube space current of said amplifier.

13. A modulated-carrier signal receiver normally responsive to signals having a wide range of signal input intensities, including a signal-translating channel, means for tuning said receiver to resonance with a desired signal, means for producing an audible response to received signal-carrier modulations, means responsive to received signal intensity for maintaining said audible response within a relatively narrow range, said last-named means having toward variations in signal intensity a response sufficiently rapid to follow closely variations in the signal output intensity of said stage in the vicinity of resonance with said desired signal, whereby audible indication of resonance is impracticable, and visual resonance indicating means connected to respond to the output of said channel.

14. A modulated-carrier signal receiver normally responsive to signals having a wide range of signal input intensities, including a vacuum-tube amplifier, means for tuning the receiver to resonance with a desired signal, means for producing an audible response to received signal-carrier modulations, means responsive to received signal intensity for maintaining said audible response within a relatively narrow range, said last-named means having a time lag so small that audible indication of resonance is impracticable, and visual resonance indicating means connected to respond to the output of said amplifier.

HAROLD A. WHEELER.

CERTIFICATE OF CORRECTION.

Patent No. 2,080,646. May 18, 1937.

HAROLD A. WHEELER.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 1, first column, line 2, for the word "said" read such; line 30, strike out "carrier-current" and insert the same before the word "signal" in line 31, page 2, second column, line 42, strike out "impedance"; page 4, second column, line 64, for "voltabe" read voltage; page 5, first column, line 45, strike out "and"; same page, second column, line 39, claim 3, for "intensities" read intensity; line 40, same claim, for "system" read receiver; line 48, claim 4, strike out "to" after "signal-carrier" and insert the same after "response" in same line and claim; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 27th day of July, A. D. 1937.

Henry Van Arsdale

(Seal) Acting Commissioner of Patents.

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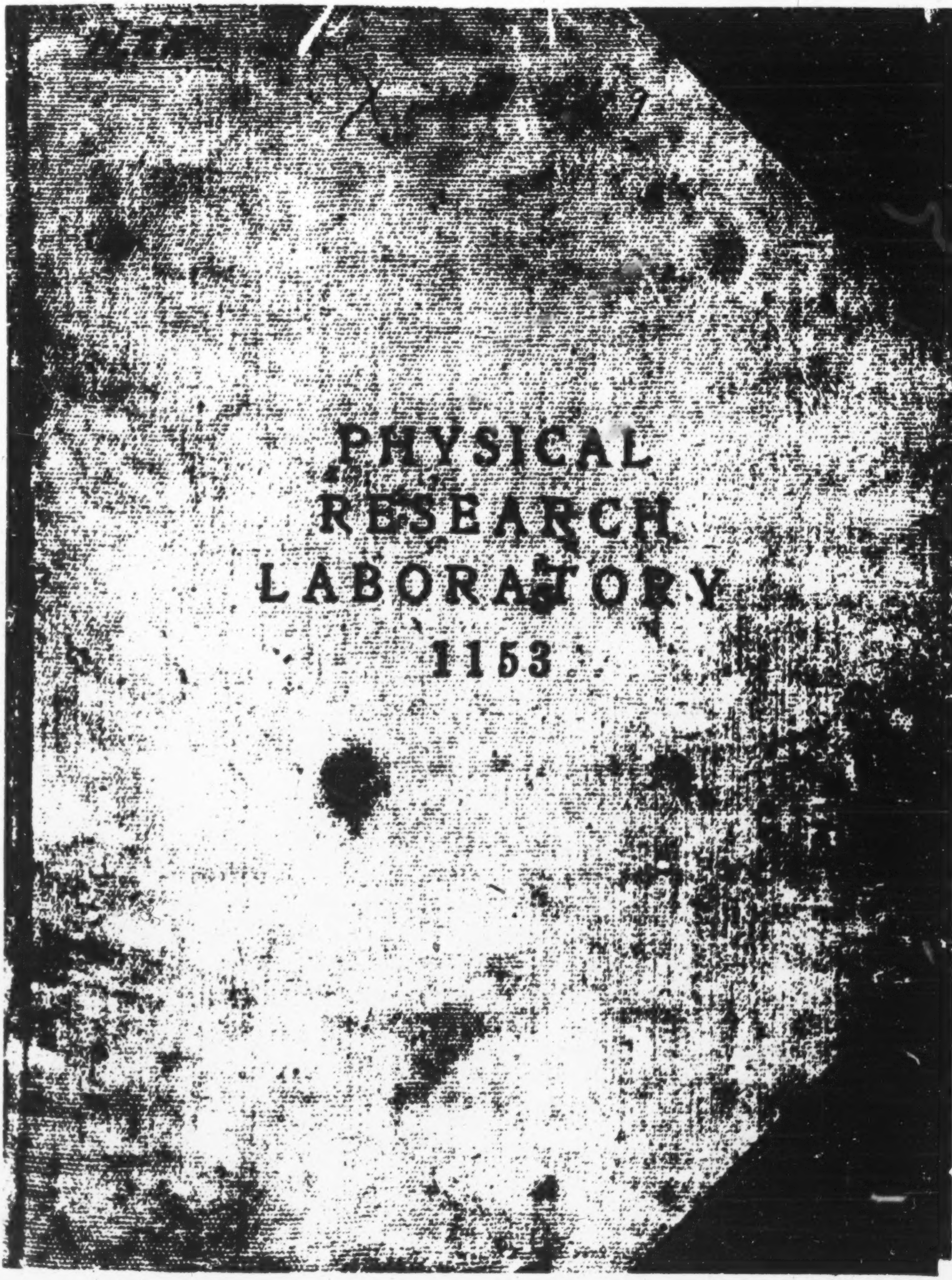
DEFENDANT'S EXHIBIT NO. 9

(accompanying Friis et al deposition--Pl. Ex. 27)



106

DATE Oct. 3 1923

Automatic and output gain control of receiving sets.

An experimental study of this was suggested by me in the beginning of August to Mr. [illegible], it followed a suggestion from Mr. [illegible] [illegible] study of distant control of receiving sets.

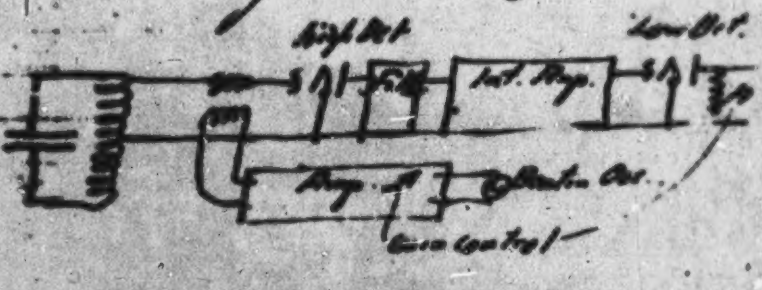
The gain control may be done the following ways:

1) Gain control of intermediate frequency amplifier (f. inst. by changing the negative grid voltage as was done in the 1920 [illegible] set or by changing number of stages used etc.).

2) Gain control of the beating oscillator signal (for inst. by changing the gain of an amplifier for the beating oscillator signal etc.).

3) Gain control of the incoming signal voltage in the antenna circuit.

or by combining schemes 1), 2) and 3).



Tube control alone seems [illegible]

The detector plate current can regulate the beating oscillator amplifier, eg. Fig. so that the output only varies between say 100 and 200 per degree, corresponding to say 1000 and 1 times [illegible].

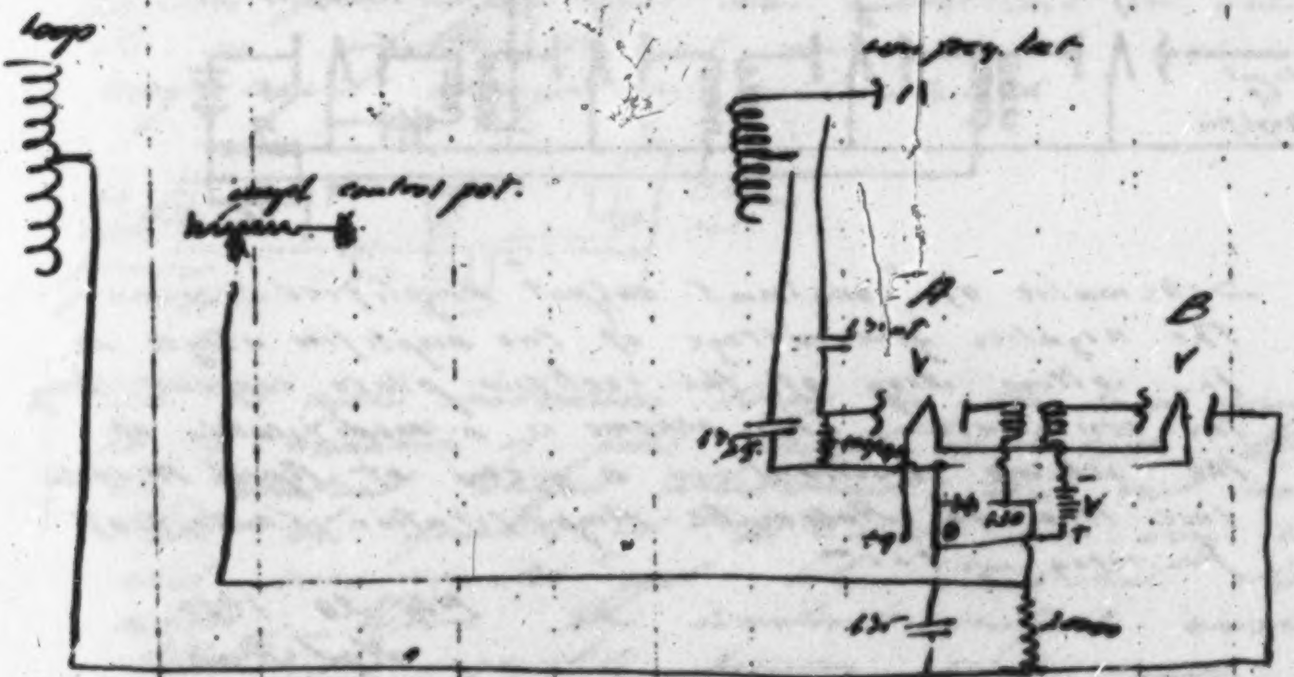
With my time key in the circuit [illegible] a key of operation changing to control this scheme with relative [illegible] and [illegible].

Oct 3 1923

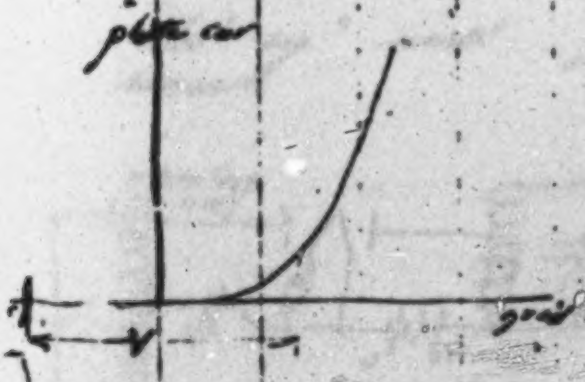
[illegible signature]

DATE Feb. 28 1928. EX-9-1381

Automatic gain control of the [illegible] scheme as it was tried [illegible] ... was as follows.



Tube A is an ordinary ampl. tube. Tube B is detector.
The characteristic of tube B.



As long as the signal voltage to tube B is below V volts the output plate current is zero and the total ampl. of [illegible] ... As soon as the voltage exceeds V it is only the peak voltage and if the plate current will change the mean grid bias of the 1st ampl. and the ampl. will drop. With 22½ volt the output was quite constant without distortion

thereafter. This [illegible] was made by me and tested by [illegible]. Feb. 28 1928
[signature]
Witness [signature]

Faces page 136 of note book

Schematic of "constant output" amplifier.
The negative grid voltage of two amplifier stages is the voltage drop of the rectifier plate current through the resistance. This scheme is a modification of the scheme described in a memo of April 14 1924 case 1450 on Automatic Amplification Control of receiving sets.—

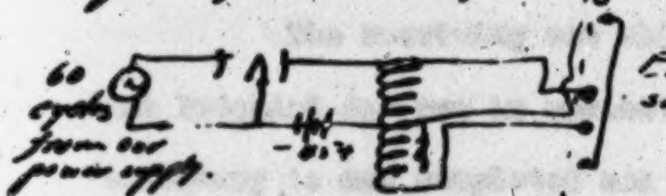
May 20 1924
H. T. Friis

Witnessed May 20 1924
Nell S. Jensen

DATE June 10 1924

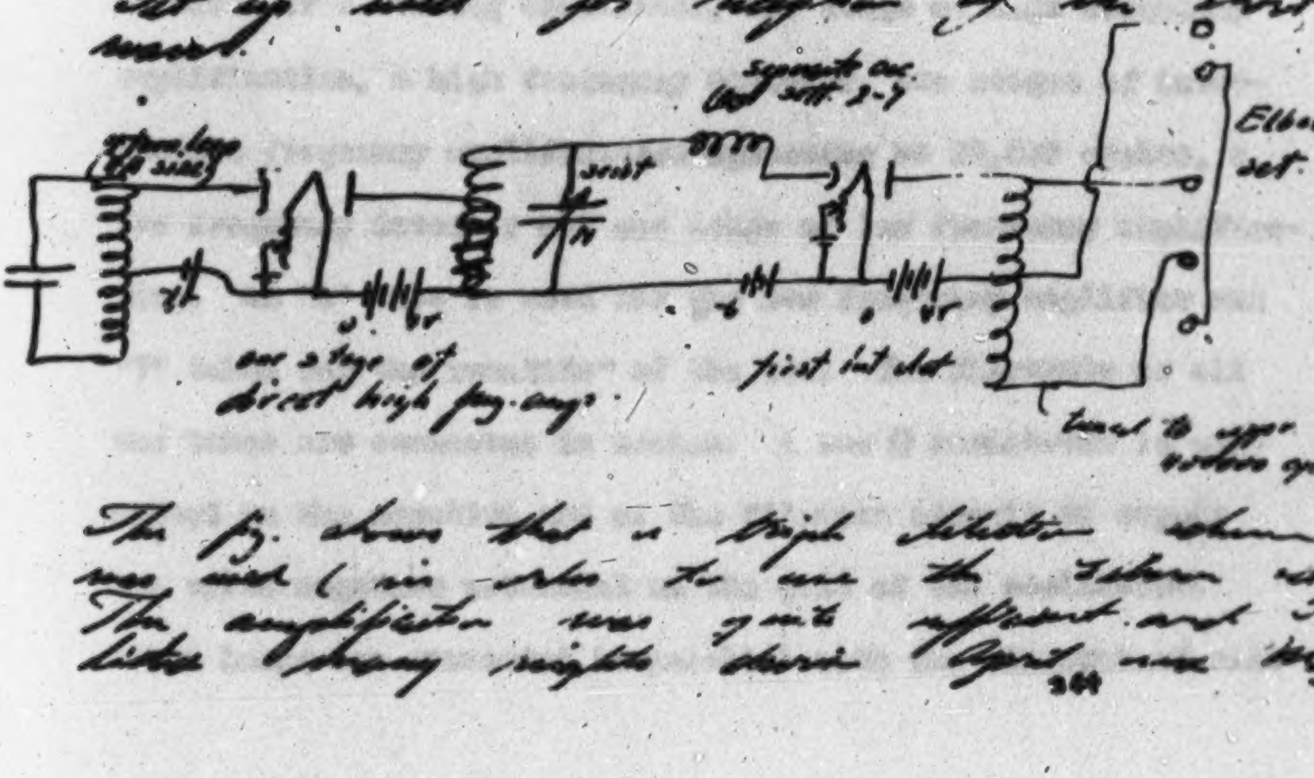
"Constant Output Set" for reception of short waves

The "Elboro" set was used for these experiments. The foll. experiment was carried out in order to see whether the set was able to allow very rapid changes in field strength.



The 60 cycle introduced losses in the loop corresponding to a variation of field strength of 60 cycles. When the constant output attachment did not work then the quality of the [illegible] was very bad and was sounded just like [illegible] short waves. When the constant output worked then the quality became good again (4 m.f. and 12000 ohms time constant) which shows the set can follow 60 cycle changes in field strength.

"Set up" used for reception of the short waves.



The fig. shows that a single selection was used (in order to use the Elboro set). The amplification was quite sufficient and I listened many nights during April and May.

DATE

to Sta. 8Y and KDKA. However the quality was only good when I listened and so I am of the opinion that the rather quality (the low notes again) were due to the transmitter itself).

DEFENDANT'S EXHIBIT NO. 9A

(accompanying Friis et at deposition--Pl. Ex. 27)

Case 14061 - Ship-to-Shore Radio Telephony Feb. 20 1924

[illegible]

The receiving set which was started November 1923 and intended for use in connection with ship-to-shore radio telephony is now completed and it is described in this memorandum. The set consists of 5 brass panels 3/16" x 14" x 19" mounted on a "relay rack". It is intended that distant control apparatus be mounted on the top panel. The next panel contains the amplifiers and detectors. Then comes a panel with loop tuning condenser and filters. The fourth panel is to be used for wave antenna equipment and the fifth is a spare.

The receiving set is of the double detection type and consists of a beating oscillator, one stage of high frequency amplification, a high frequency detector, two stages of intermediate frequency amplification operating at 30,000 cycles, a low frequency detector and one stage of low frequency amplification. An "L" tube is used for the low frequency amplifier and "V" tubes for the remainder of the set. The filaments of all the tubes are connected in series. A two Ω resistance is connected in the negative end of the filament circuit to supply two volts negative potential on the grid of the oscillator. Pilot lamps are connected in parallel with the filament of each

tube which light when a tube burns out. 120 volt lamps are connected in series with the plate of each tube which light in case of short circuit. The filament and plate circuits are grounded thru 1.75 mf condensers as indicated on the connection diagram. Jacks are connected in series with plate circuits of all the tubes.

The negative potentials on the grids of the two detectors and the high frequency amplifier are controlled by 400 Ω potentiometers.

All the apparatus is mounted on two brass panels. The filters, tuning condensers and oscillator coil are on one panel and the remainder of the apparatus on the other panel.

The loop and oscillator are tuned with two condensers mounted on the same shaft but insulated from each other. Each of these condensers has another condenser connected in parallel with it so that the loop and oscillator tunes can be set 30,000 cycles apart. After this initial adjustment has been made the double condenser will tune both loop and oscillator over a wide range of wave-lengths.

Oscillator

The oscillator is wound on a 1-3/8" tube set in a removable mounting so that different coils can be plugged in. The winding is of the figure 8 type with 40 turns each in the

grid and plate coils. No. 28 DSC wire was used. The pick-up coil consists of 1.5 turns 1/8" from the grid coil. This was found to give the best results.

High Frequency Amplifier

The high frequency amplifier is used simply to control the output of the set. The amplifier is resistance coupled to the high frequency detector with 12,000 Ω in the plate circuit, 50,000 Ω in the grid circuit of the detector and coupled with a 150 mmf condenser. A wide range of amplification (1:200) is secured by varying the negative potential on the grid with a potentiometer.

A balancing condenser is connected from the end of the loop opposite the grid to the plate of the high frequency amplifying tube. If this is not done too much energy passes thru the grid to plate capacity of the tube.

The maximum amplification of this amplifier was about 1.5 times so that the control consists mainly of reduction in volume.

Intermediate Frequency Amplifiers

The high and low frequency detectors are coupled to the intermediate frequency amplifiers thru two similar filters. The filters consist of tuned circuits capacity coupled. The coils have an inductance of about 25 mh and are wound of 10 No. 28 DSC wire on four grade "C" iron dust rings. There are

4 layers of wire on the inside and two outside. A 500 mmf General Radio variable condenser is connected in parallel with each coil. The coupling condensers are 250 mmf General Radio variable condensers. The center of the grid coil in the first filter is connected to ground so that the grid can be connected to one end of the coil and the other end connected thru a small condenser to the plate thus neutralizing the grid to plate capacity of the tube. In the second filter the B battery is connected to the center of the plate coil and the grid to plate capacity of the second amplifier tube neutralized in the same way as the first one.

The filter is adjusted by carefully tuning both filters to 50,000 cycles with very weak coupling. Then the coupling of both filters is increased until the desired band width is obtained. The resonance curve will have two peaks which can be kept the same height by slight adjustments of the tuning condensers. A 100,000 Ω resistance had to be connected across the plate coil in the first filter and a 40,000 Ω resistance across half the plate coil in the second filter to keep the drop between the peaks from exceeding six miles. These resistances do not materially raise the resonance curve between the peaks but do cut down the height of the peaks thus flattening the top of the curve.

The two amplifier tubes are coupled with a special transformer. The primary and secondary windings are wound side

by side on a spool with a thin partition between them. Each winding consists of 1000 turns of No. 36 DSC wire. Four grade "C" iron dust rings were put thru the spool by breaking them in half and then putting them together again. The rings were taped together and held firmly in place by the hard rubber mounting for the transformers. The mounting was made in two halves, the insides being hollowed out to fit the rings. The amplification of the two stages of the intermediate frequency amplifier is 500 times. Maximum total high frequency amplification of the set is 2000 times.

Low Frequency Amplifier

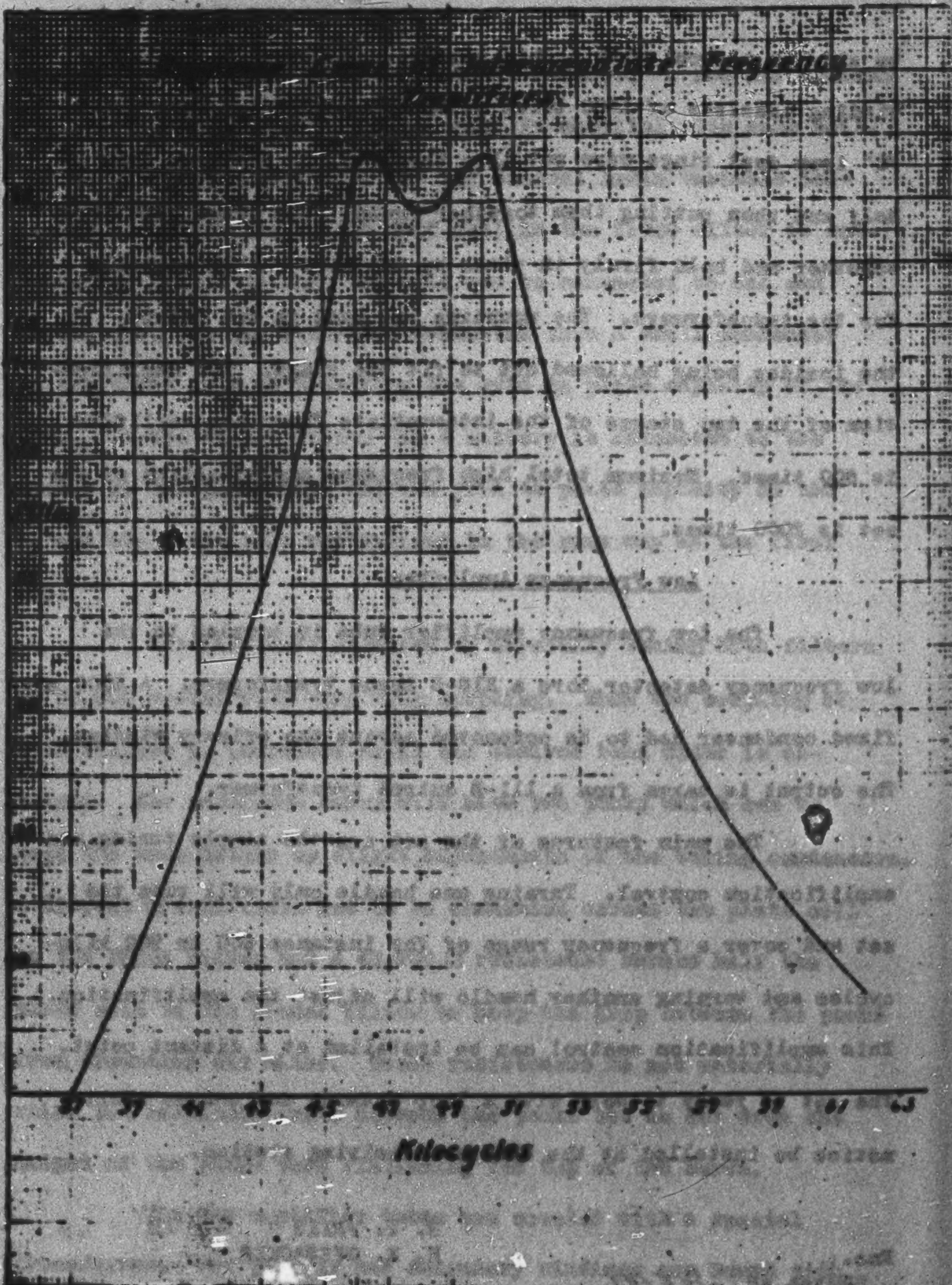
The low frequency amplifier tube is coupled to the low frequency detector thru a 219-E input transformer. A 2000 mmf fixed condenser had to be connected across the primary winding. The output is taken from a 111-B output transformer.

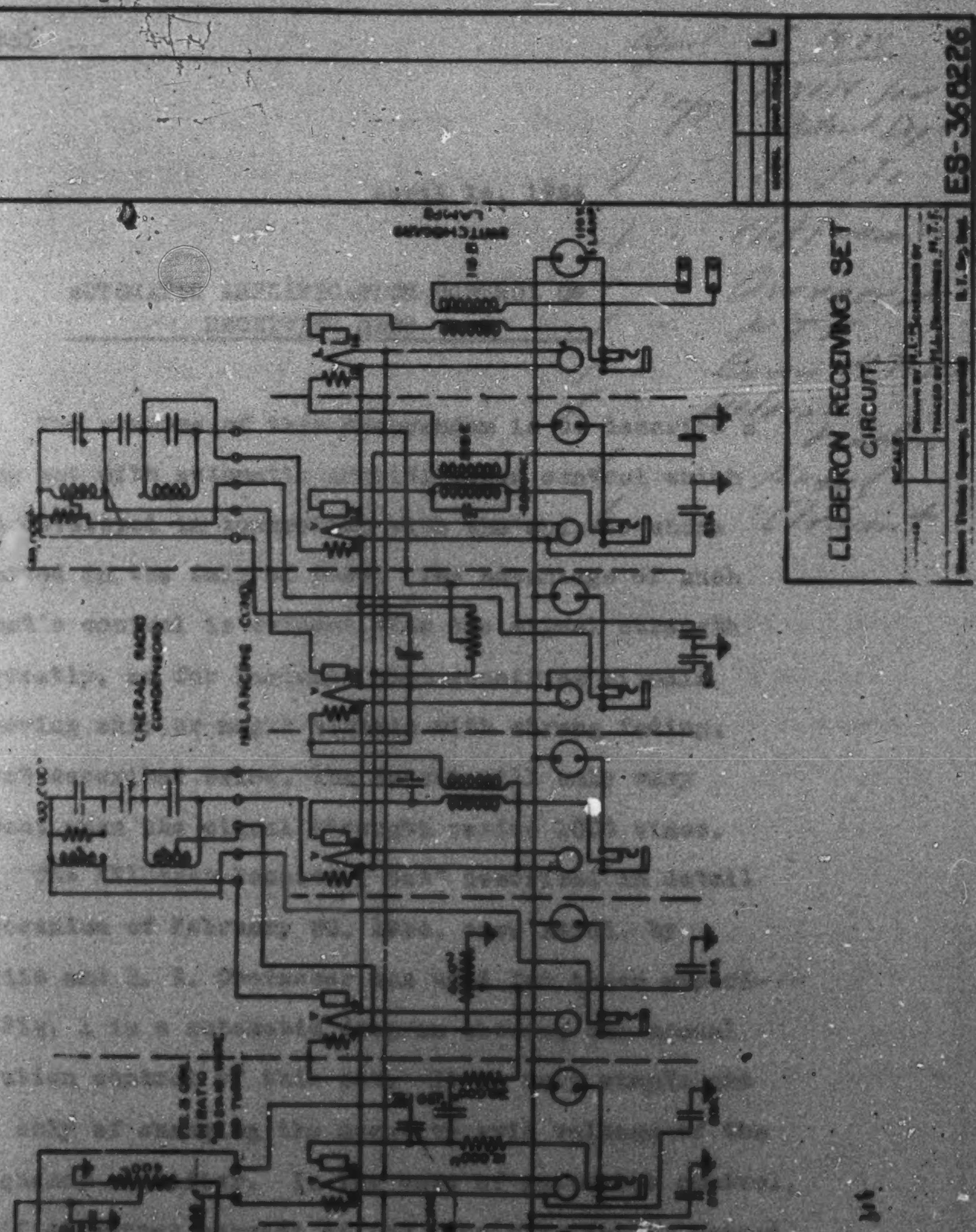
The main features of the set are the simple tuning and amplification control. Turning one handle only will tune the set and cover a frequency range of for instance 600 to 900 kilocycles and turning another handle will adjust the amplification. This amplification control can be installed at a distant point. The set is ready to work with a loop antenna and can on short notice be installed at the Elbéron receiving station.

H. T. FRIIS - AE
H. B. OVERACKER

Enc.:
Sketch ES- 368181
ES- 368226

Sketch No. ES 368181




CLBERON RECEIVING SET
CIRCUIT
ES-368226
ES-368226

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PLAINTIFF'S EXHIBIT NO. 9-A-2
(accompanying Betts et al deposition--Pl. Ex. 28)

Case 14561

April 15 1924
1 copy HWN for Patent Dept
1 to File
1 Clifford
1 Overacker
1 H.T.F.
1 Brown
1 Delocain
1 Gordon
1 Hugel
1 Clement

April 14, 1924

AUTOMATIC AMPLIFICATION CONTROL OF RECEIVING SETS

The purpose of this memorandum is to describe a receiving set with automatic amplification control which has been developed in connection with the ship-to-shore work started in the fall of 1923. The advantage of such an automatic control is evident when the signal strength varies greatly, as for instance when receiving signals from a moving ship or night signals with strong fading. In the set described below, the output will only vary 10 per cent when the signal strength varies 1000 times.

The "Elberon Receiving Set" described in detail in a memorandum of February 20, 1924, case 14561, by H. T. Friis and E. B. Overacker was used for these experiments. Fig. 1 is a schematic diagram showing the manual amplification control of this set. It is very simple and consists only of changing the negative grid voltage of the high frequency amplifier. In the case of automatic control, the rectified output current of the receiving set is passed through a large resistance and the voltage drop through this resistance is used as negative grid voltage of the high frequency amplifier; therefore, the larger the output the greater the negative grid voltage which reduces the amplifi-

- 2 -

cation. Figure 2 shows a diagram of this automatic control unit and its connections to the receiving set. The figure shows that one stage of intermediate frequency amplification is added to the intermediate frequency amplifier itself before the intermediate frequency currents are rectified. Two extra batteries are required for the rectifier tube. Otherwise the same A and B batteries are used for the whole set. Fig. 3 illustrates the action of the negative grid voltage E_c of the rectifier (see Fig. 2). It is clear that the larger the negative grid voltage E_c^1 the more nearly constant the output voltage e of the set will remain because a smaller percentage change in e will produce the same rectified current i_p. Fig. 4 gives the variation in output voltage of the set for different values of input voltage.

It may be pointed out that this control naturally requires a carrier current in the signal. The speed of the control is determined by the time constant of the resistance R and the by-pass condenser C (see Fig. 2) which is R.C. = 20,000 x 5.10^{-6} = 1/10 sec.

H. T. FRIIS

H. E. OVERACKER

Enc.

3 Sketches.

SE.

WESTERN ELECTRIC COMPANY, INCORPORATED ENGINEERING DEPARTMENT NEW YORK, U. S. A.	DATE ISS.	DRAWN ENGINEER N.T.E.	ES.

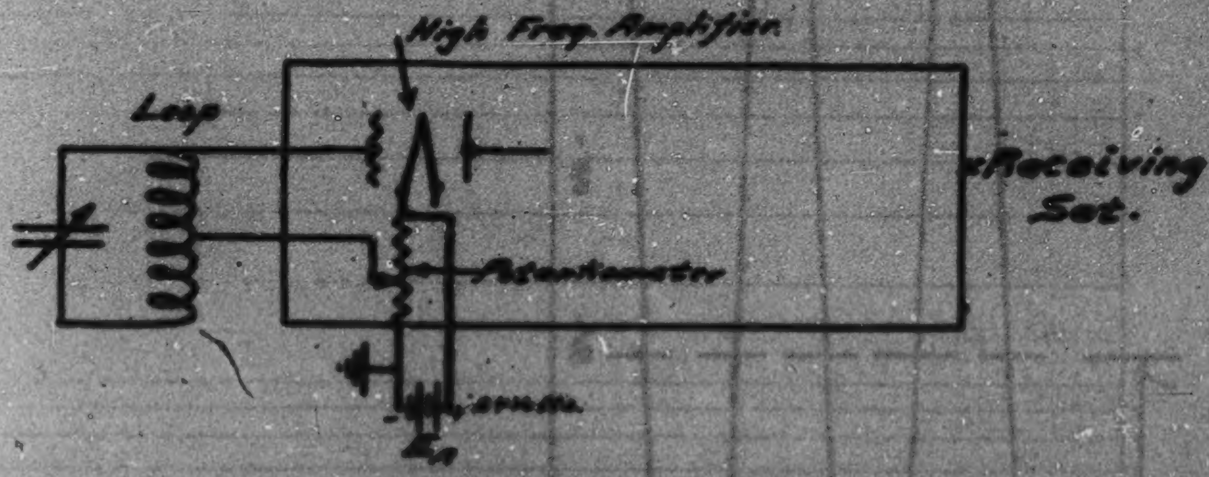

Fig. 1.

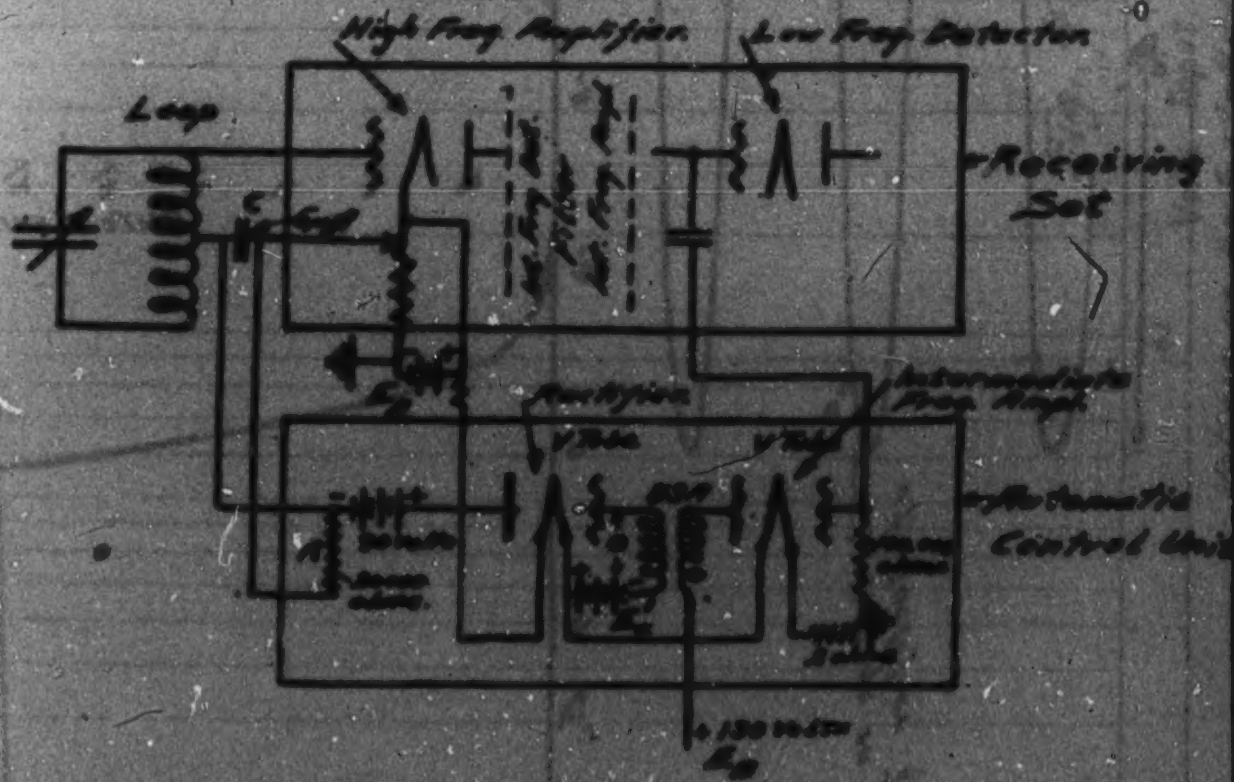

Fig. 2.

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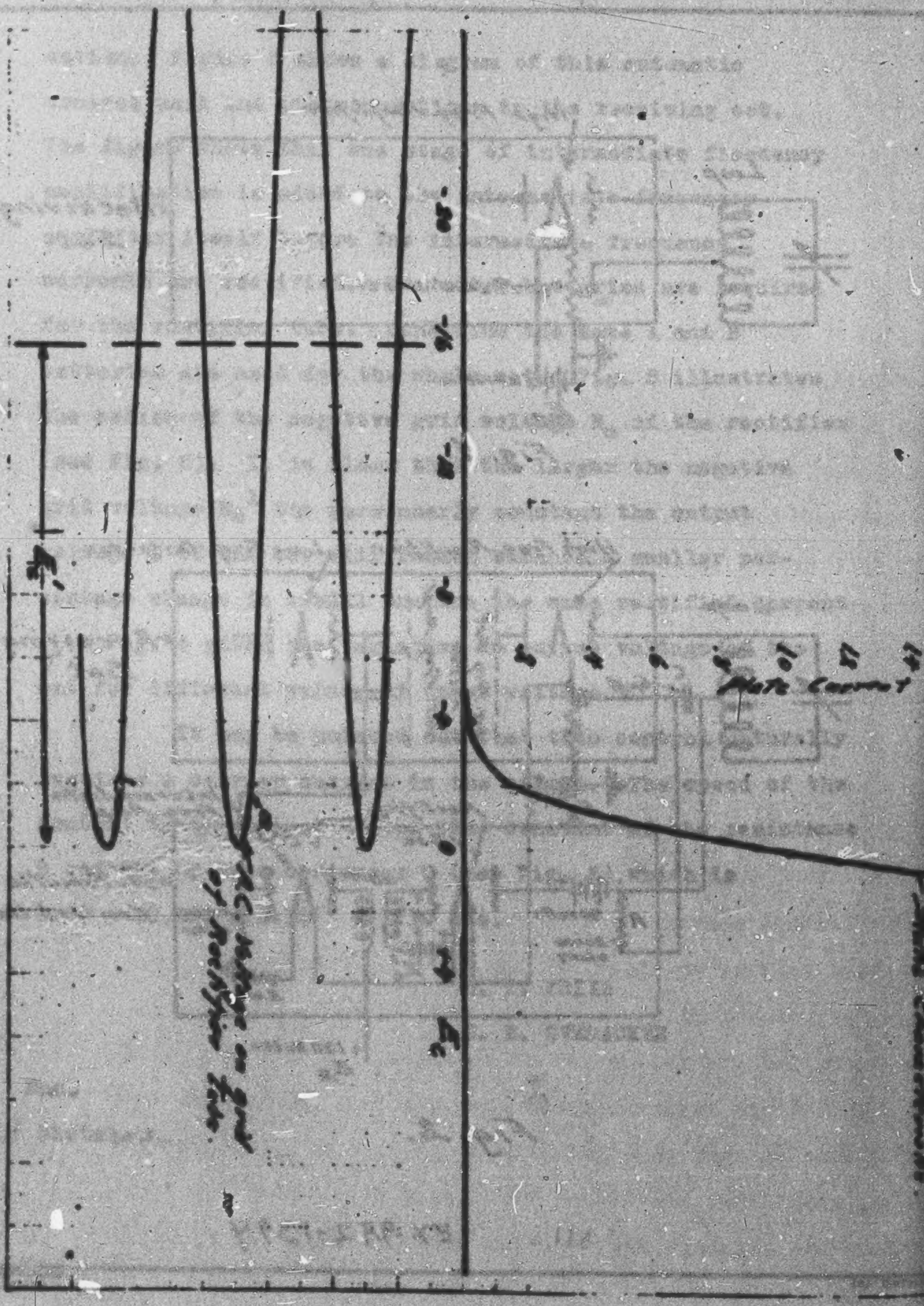

Fig. 3.

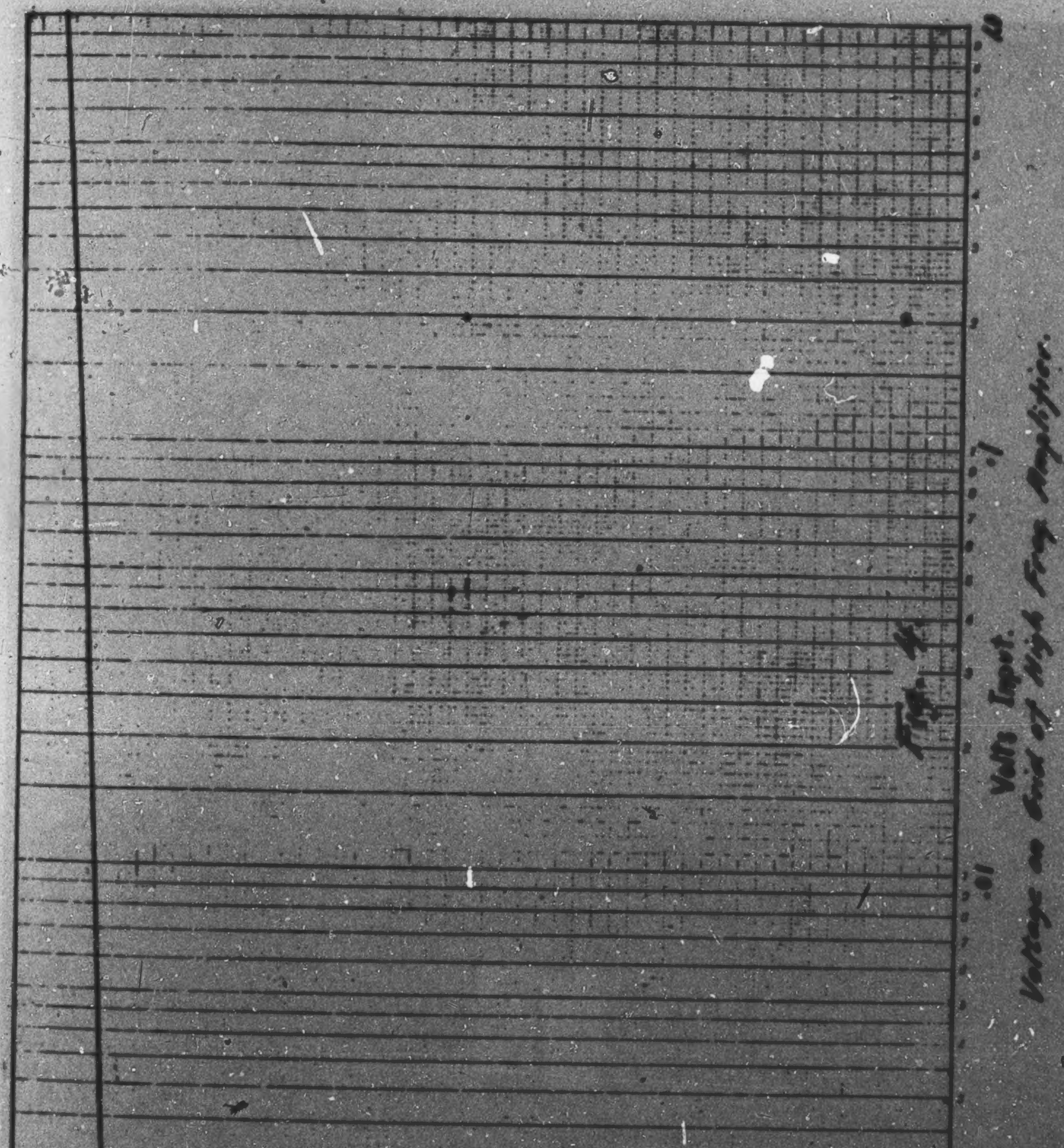
Volts Input.
Voltage on Grid of High Freq Amplifier.
Volts Output
Voltage on Grid of Low Freq Detector.
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
.001
.01
.1
1.0

Fig. 4.

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DEFENDANT'S EXHIBIT NO. 9B-1

(accompanying Friis et al deposition--Pl. Ex. 27)

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DEFENDANT'S EXHIBIT NO. 9B-2

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DEFENDANT'S EXHIBIT NO. 9B-5

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DEFENDANT'S EXHIBIT NO. 9B-6

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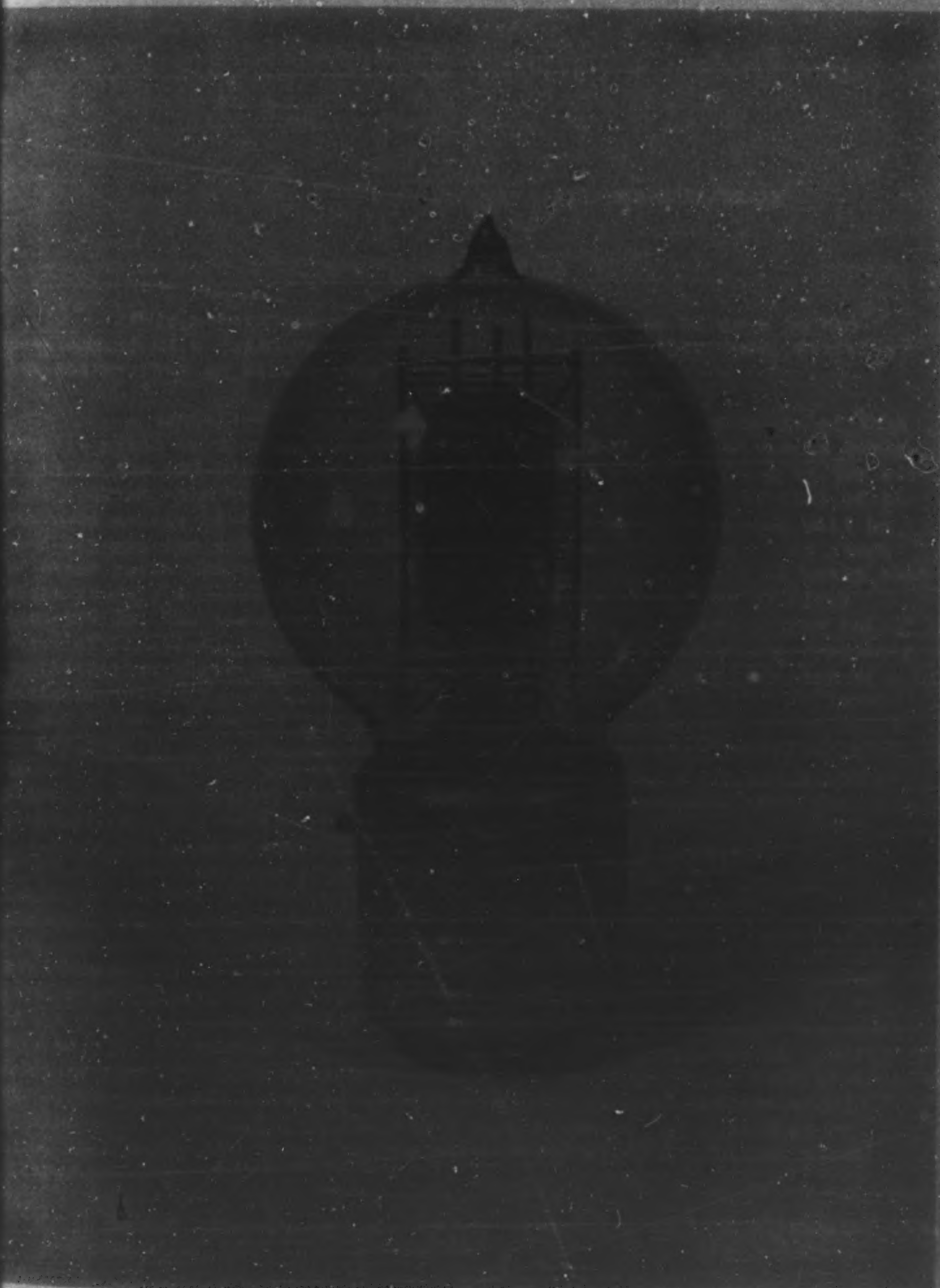
DEFENDANT'S EXHIBIT NO. 9B-7

(accompanying Friis et al deposition--Pl. Ex. 27)



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PLAINTIFF'S EXHIBIT NO. 1-A

(accompanying Betts et al deposition--Pl. Ex. 28)

Preliminary Study of A Double Detection AC Operated Radio Receiver - Case 33079

311-PHB-9/14/28-KK

MEMORANDUM FOR FILE

This memorandum outlines the work about to be done in the development of a radio receiver of the double-detection type, deriving its energy from an alternating current source.

A tentative circuit diagram which will form the basis of this work is given on ES-403489. This receiver will use twelve vacuum tubes, eight of the 280-D type and four of the 205-D type. Referred to the circuit diagram, the antenna circuit will be tuned similarly to that of the ten shop models of the 6-A Radio Receiver. Cycloidal coupling will be used between the antenna circuit and the secondary circuit. One stage of tuned radio frequency amplification is planned. It will be noted that plate circuit modulation is employed between the modulator or first detector and the oscillator. This is a departure from the 4-type radio receiver practice. There will be three stages of intermediate frequency amplification employing a mean frequency of about 80 kcs. Instead of designing flat transformers to be used with the three stages, followed by one filter to supply the selectivity, the amplifier as a whole, will be designed to give the proper characteristics, probably employing a broad filter between the modulator and the first amplifier and a sharp filter between the last amplifier and the second detector. For the sake of stability, one balanced output transformer will be used and possibly one stage resistance coupled. Resistance coupling offers a ready means of controlling the gain of the intermediate frequency amplifier, although the circuit given may be changed from that shown in the diagram. Following the second detector there will be one stage of audio frequency amplification employing the 280-D vacuum tube and a push-pull stage employing 205-D vacuum tubes with characteristics similar to the audio frequency portion of the 6-A Radio Receiver. Two 205-D vacuum tubes will be used in the rectifier. The filter circuits in connection with this rectifier will be similar to that explained in connection with the second laboratory model of the AC radio receiver described in memorandum for file of 8/14/28. The circuit diagram shows an additional filter section particularly applied to the filaments of the 280-D vacuum tubes. It will also be noted that every 280-D tube in the circuit has its own grid and plate filter.

Radio frequency noise from the power line will be eliminated with two 5-B chokes and two 21-AC condensers as in the 6-A radio receiver.

-2-

It is planned to use signal lamps across the filaments of each of the 280-D tubes in order to indicate which of the 8 tubes may have burned out. It is further planned to make every effort to reduce this set to a two control set; one for frequency selection and one for gain.

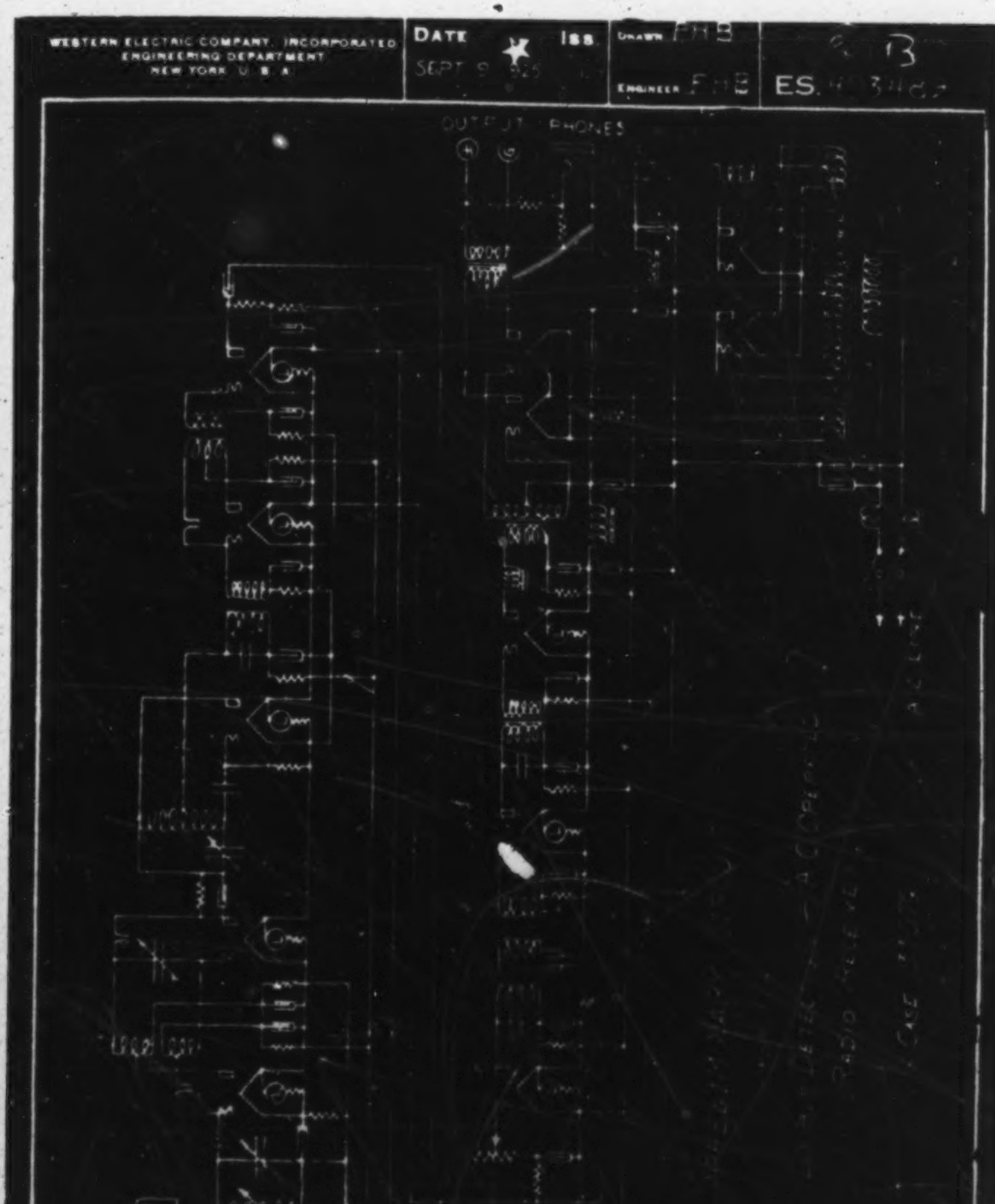
P. H. BETTS

Att.

ES-489489

P.H.B.
S.E.a.
E.L.

PLAINTIFF'S EXHIBIT NO. 1-B
(accompanying Betts et al deposition--Pl. Ex. 28)



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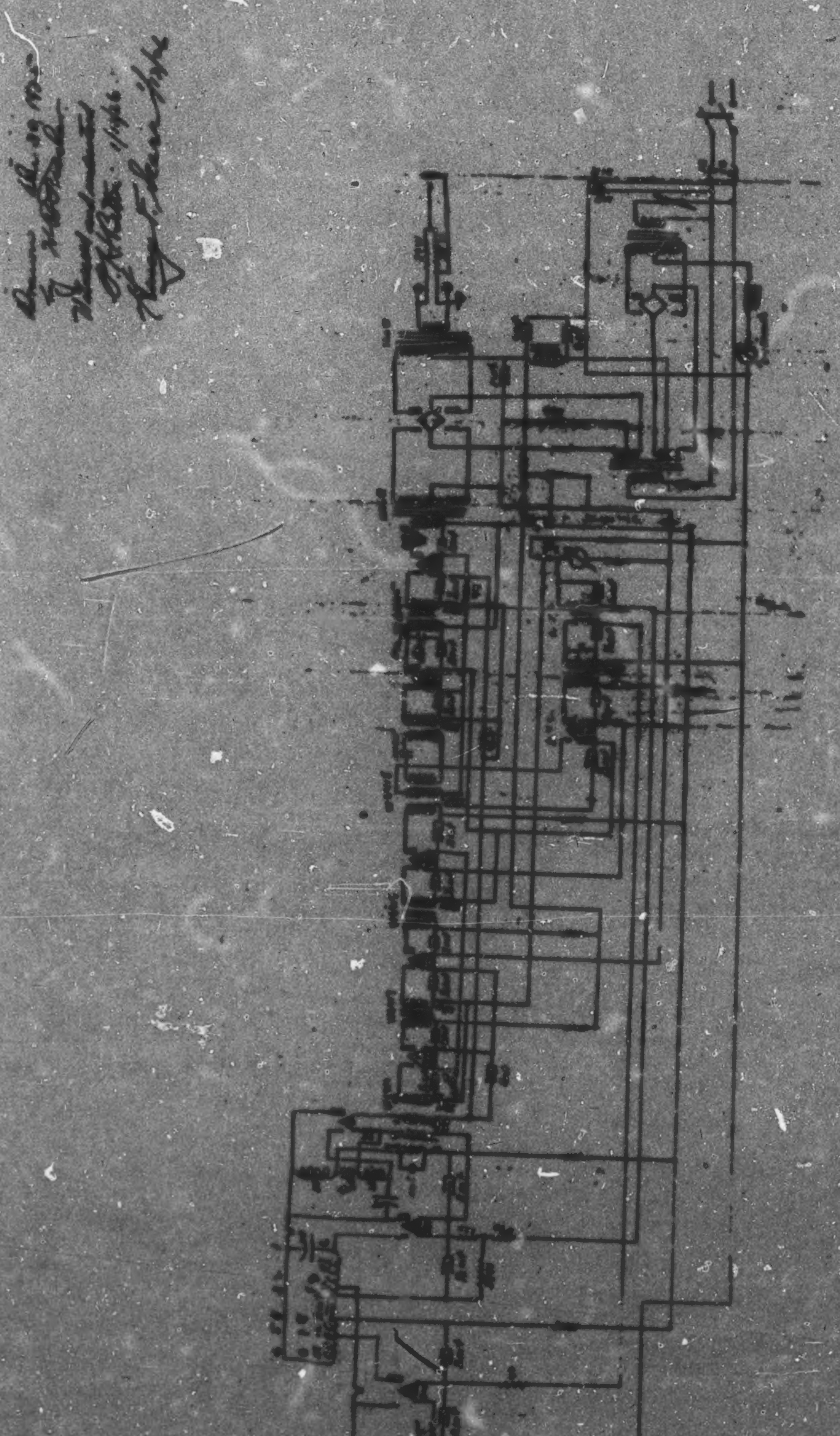

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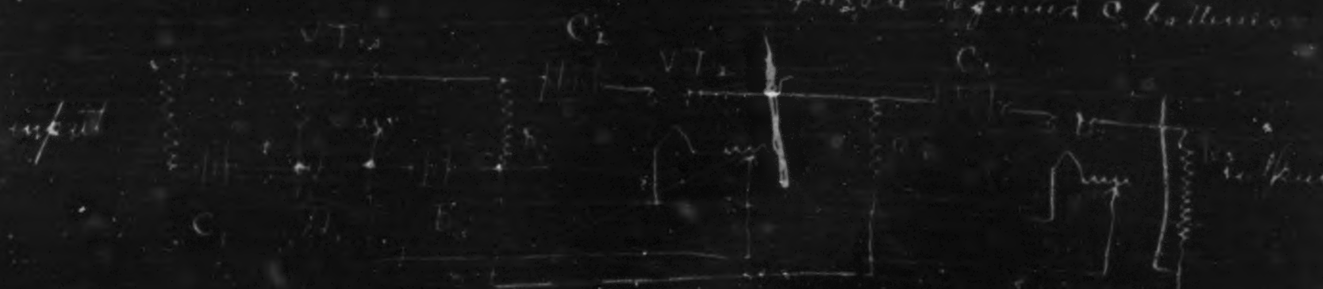
PLAINTIFF'S EXHIBIT NO. 3-A
(accompanying Betts et al deposition--Pl. Ex. 28)

[illegible] 1926

Suggestion for [illegible]

Wherein the [illegible] A B and C batteries are furnished by one high tension source, battery or rectified A.C.

Fig [illegible] usual form [illegible] amplifier showing common A and B batteries but separate required C batteries



In the above circuit C_2 and C_3 [illegible] a potential of B_1 and [illegible] to maintain.

Fig [illegible] [illegible] [illegible] B and [illegible] [illegible]

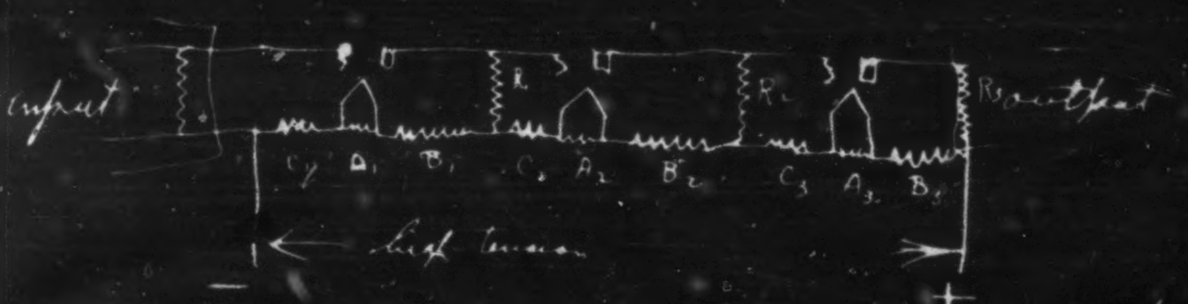
It [illegible] from above [illegible] that if the plate [illegible] voltage [illegible] obtained by resistance drops and the source of supplied voltage be equal to the [illegible]

3A/1

30

1st [illegible] 6

of the required A B and C batteries, the system can be made to operate. This high tension can be obtained readily from rectified a-c and should be a much more portable and compact unit than when the batteries otherwise required are used. The circuit is shown in Fig 3.



If 215A tubes are used the space currents will be negligible in comparison to filament current so that pile up of space currents thru successive tube filaments on negative side, is unimportant. But if 230D tubes be used each filament should have a suitable bypass resistance not only to handle the plate currents but to prevent opening a high tension circuit. The latter requirement is important even in the case of 215A tubes. The above circuit shows such by-pass resistances.

This circuit was evolved in developing the automatic gain control for the DDAC[illegible] receiver which is in effect one stage of DC amplification.

[illegible], January 2, 19[illegible]

The above circuit Fig 3 is substantially the same as explained to and understood by the undersigned on or prior to Nov. 28, 19[illegible]

[illegible] [illegible]

[illegible]

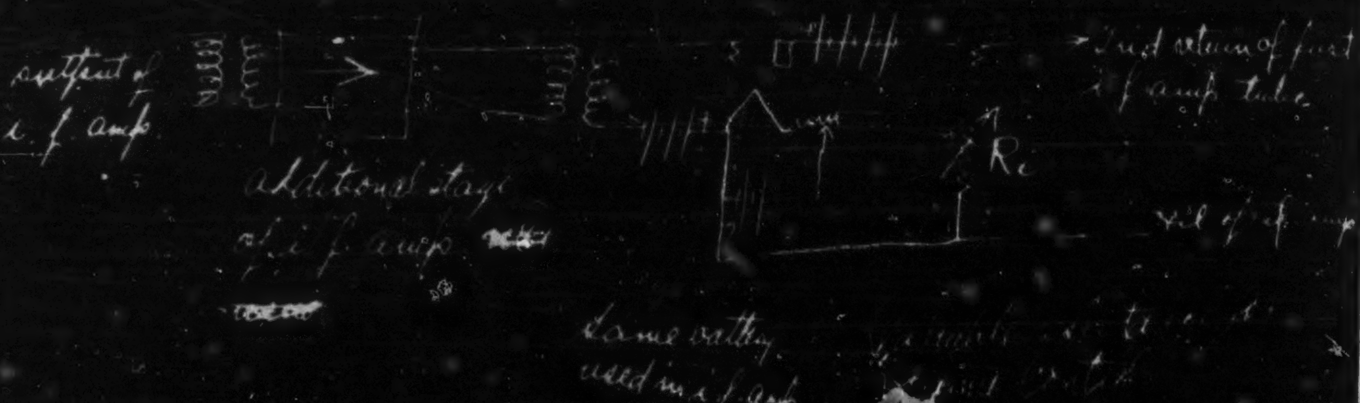
34/3

PLAINTIFF'S EXHIBIT NO. 3-B
(accompanying Betts et al deposition--Pl. Ex. 28)

Ex 3b January 4, 1926

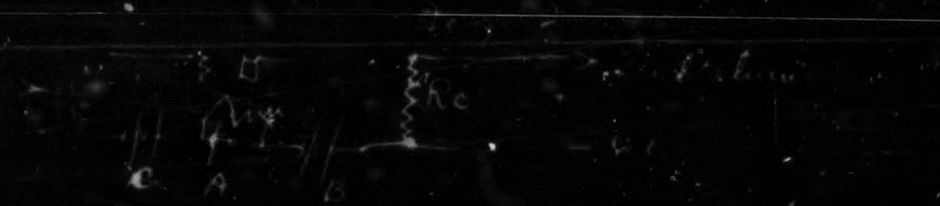
Suggestion for modified automatic Gain Control to use one source of e. m. f. in place of A B and C batteries

Figure 1



The circuit of figure 1 was adopted in order [illegible] the filament to be lighted from same battery as the receiver's i f amplifier associated with the automatic gain [illegible]

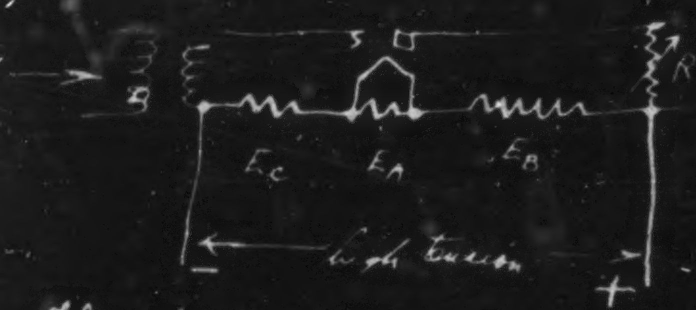
If however separate A B and C batteries [illegible] the circuit could be as follows



[illegible]

through the filament ... so much as may be ... circuit would be opened ... filament would burn out, it is advisable to shunt the filament with a resistance taking only a small current normally but which will prevent the total voltage being produced across these terminals. Such a resistance is shown in Fig. 3

Fig. 3



The specific application is in the case of the a.c. operated super heterodyne (double detection) radio receiver in which the tube filament is supplied from a rectified a.c. source and wherein E_B (?) is obtained as above excepting that part of the resistance producing E_B is made up of filaments of other tubes.

It should be noted ~~also that~~ if any other circuit requiring more or less current than the one concerned were to be connected in series with the high tension source the correct current can be obtained in each circuit by using a suitable bypassing resistance on the circuit taking the lesser current. This is illustrated by the resistances across the E tube plates in the 6 A receiver where the E tubes do not pass sufficient current for the lighting of the 230 D filaments. To save on apparatus the resistances across the E tubes also serve to form a potentiometer to supply reduced voltage to the plates of the 230 D tubes.

W. Henry F. Scott 1/5/26 [illegible] 3B/2 ... Jan 4 1926

PLAINTIFF'S EXHIBIT NO. 3-C
(accompanying Betts et al deposition--Pl. Ex. 28)

Ex 3C

The circuits shown in Fig 3 of the description of a d.c. amplifier, and Fig. 3 of a modified automatic gain control, dated Jan 2 and 4 1926 respectively were conceived on or prior to November 28th 1925 by reason of the following:

1. Measurements were made Nov. 28th, 1925 as indicated in Mr. F. [illegible] notebook # 311 B49 in measuring gain control by means of grid bias applied to the first two intermediate frequency amplifier tubes.

2. Effect of grid bias insufficient when applied to one tube to be used for automatic gain control. Hence automatic gain control was contemplated for use in the IDAC-1 receivers at this date.

3. Automatic gain control would not have been considered if separate additional batteries had been required. Hence the circuits shown above wherein one source of potential could be used in place of several batteries must have been conceived prior to the date above, namely Nov 28th 1925.

We the undersigned in support of the above that the circuits mentioned were conceived, [illegible] and understood by us on or about the 28th of November 1925.

R. L. Betts
Henry [illegible]
[illegible]

3C

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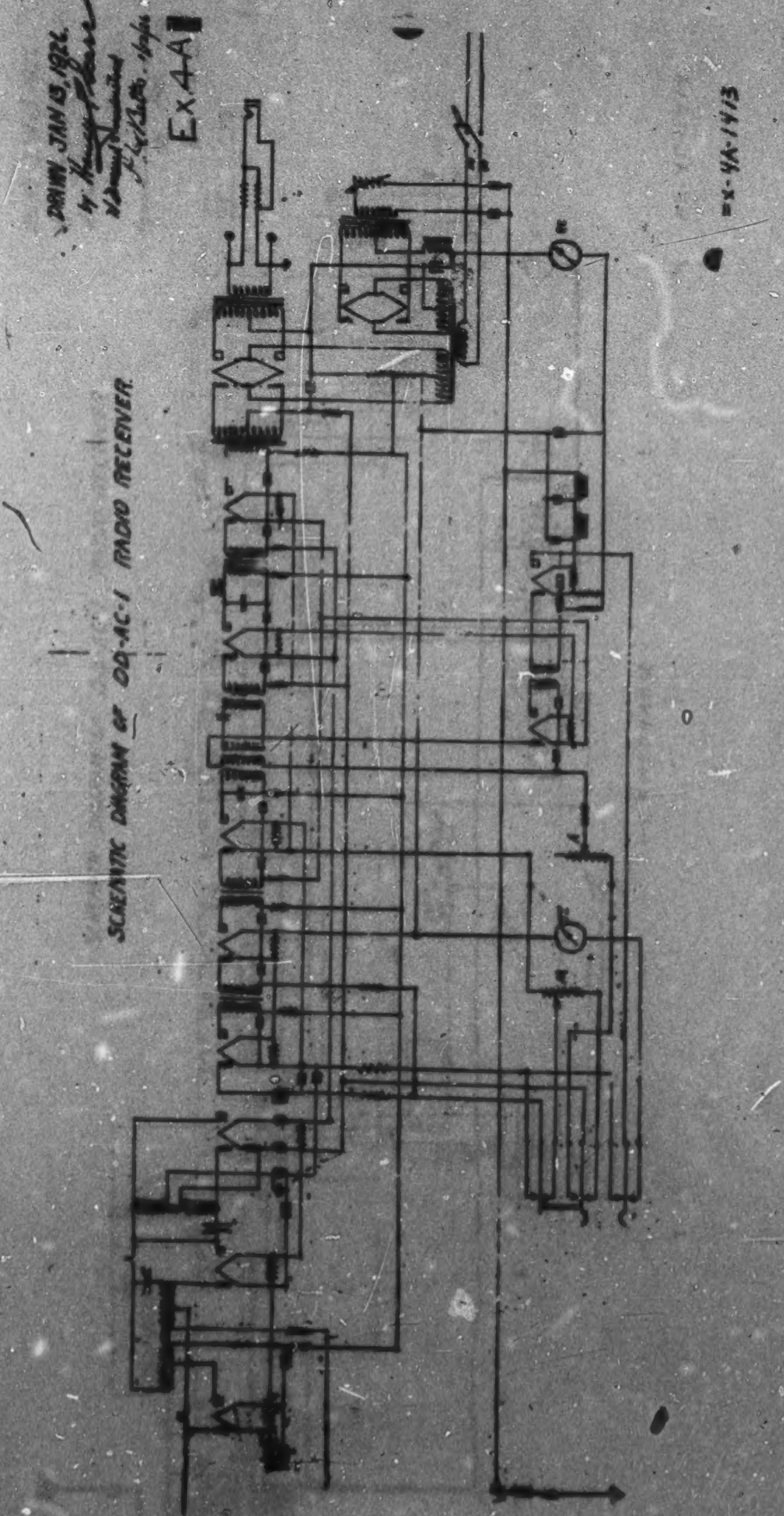

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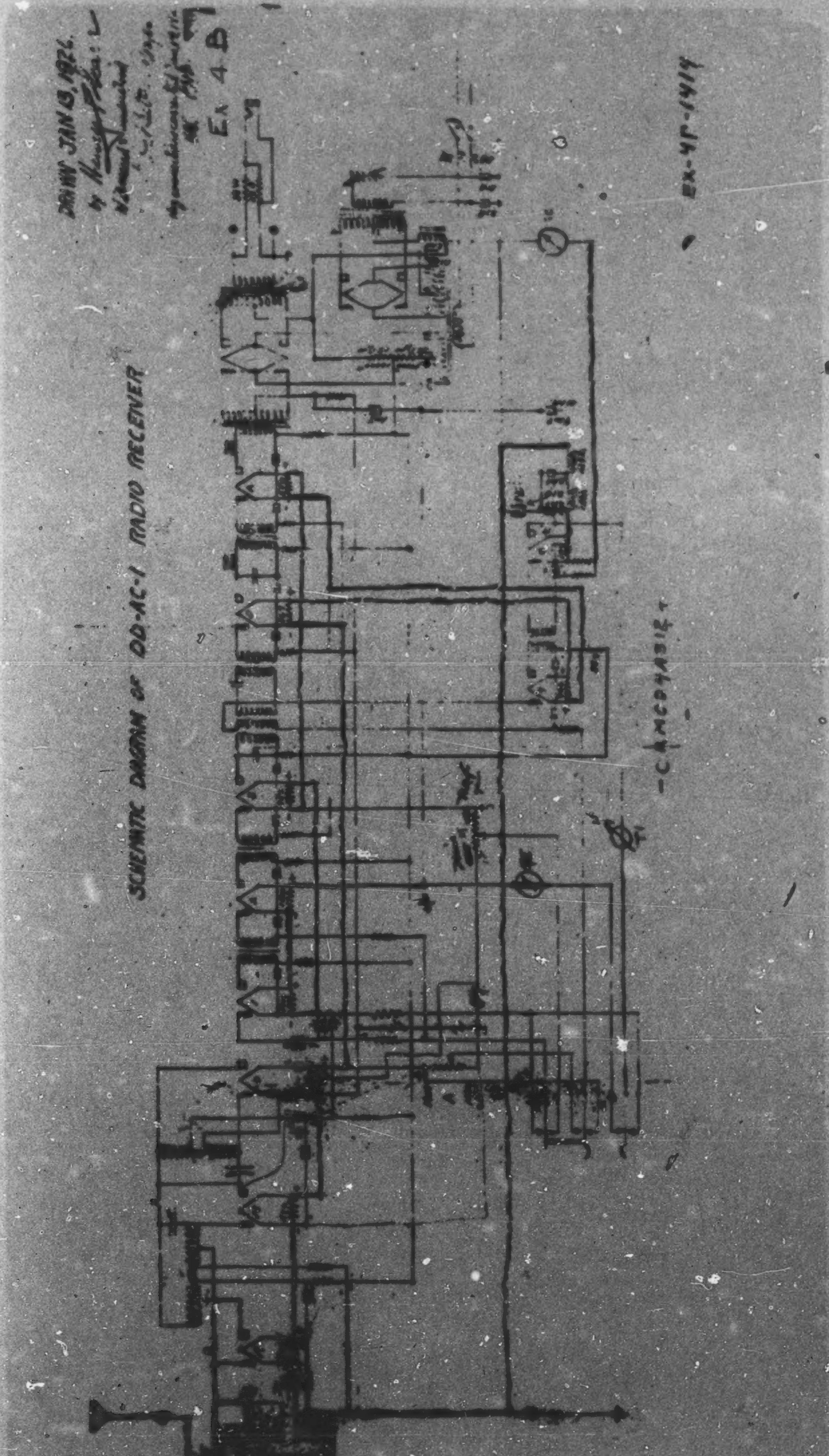

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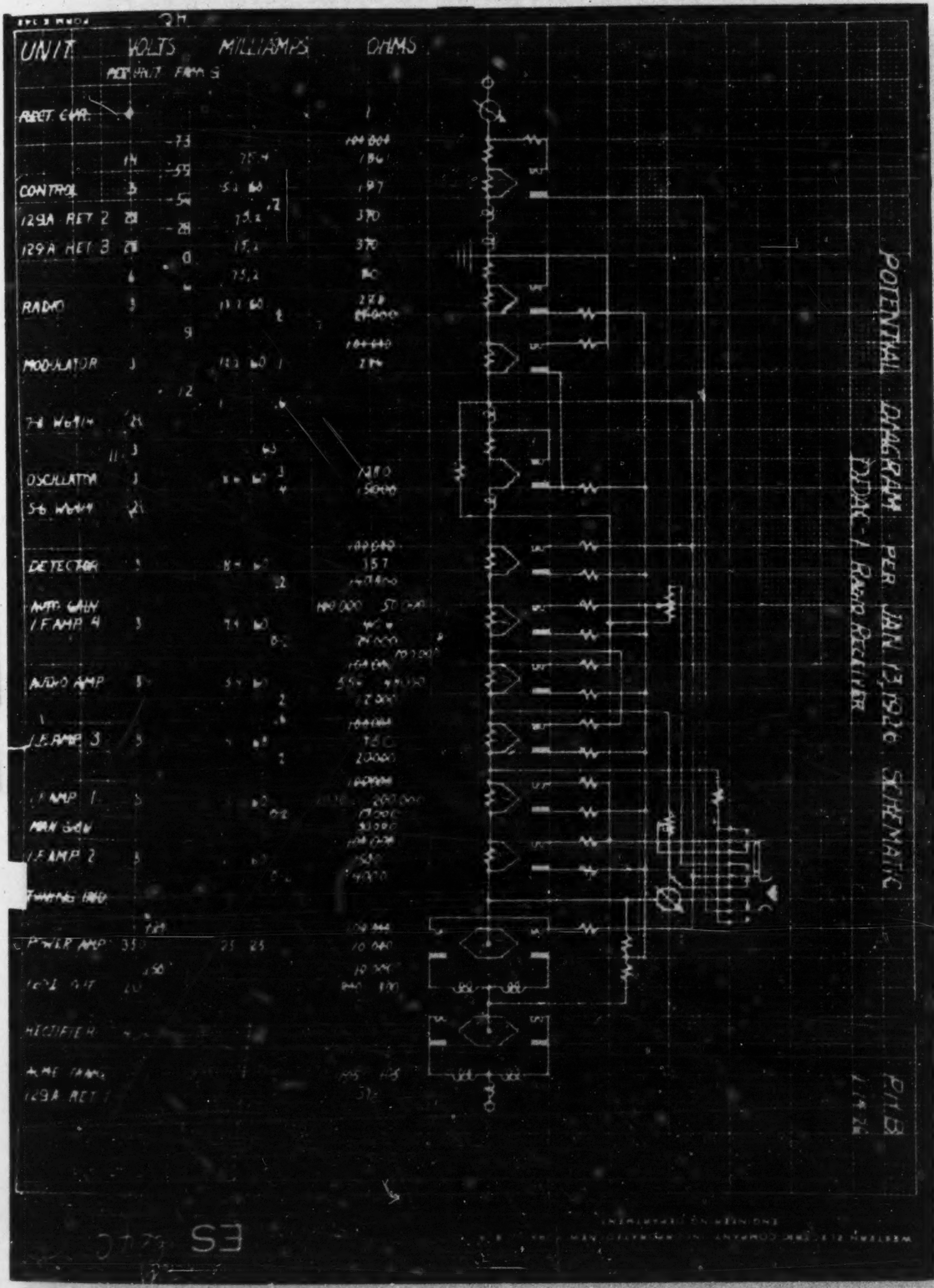

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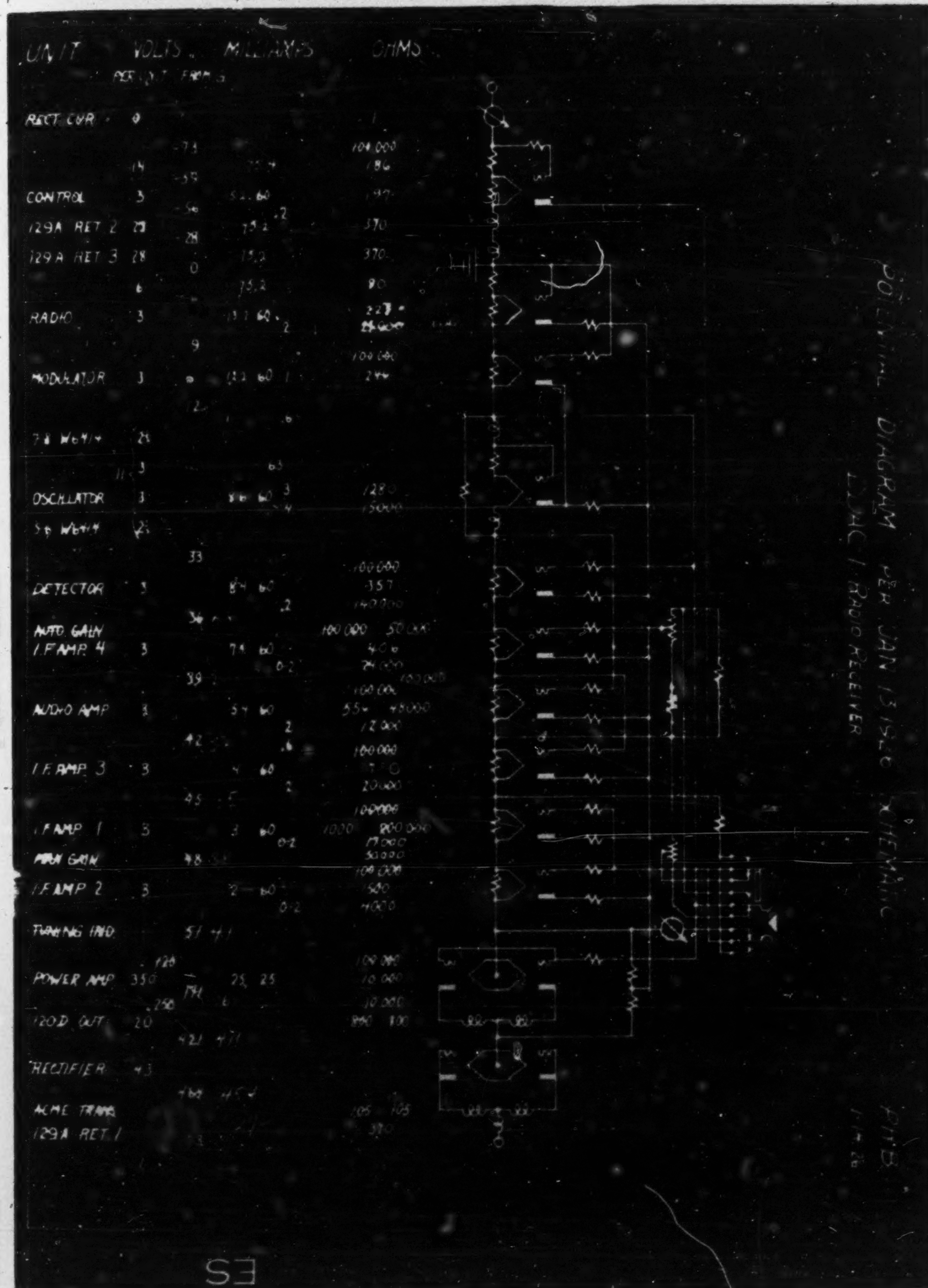

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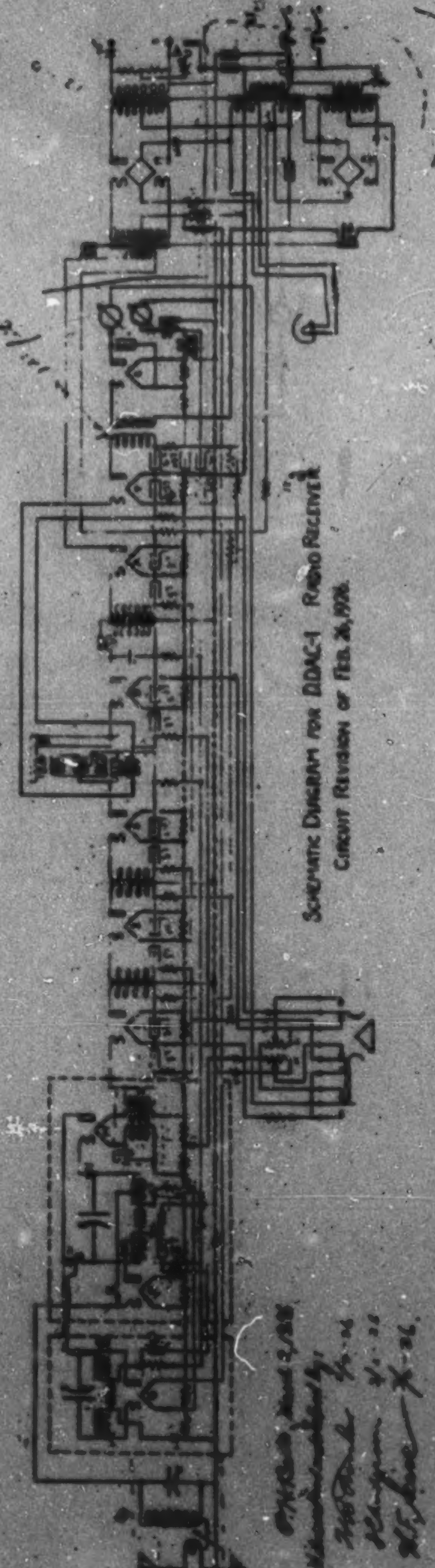
See Extra issue



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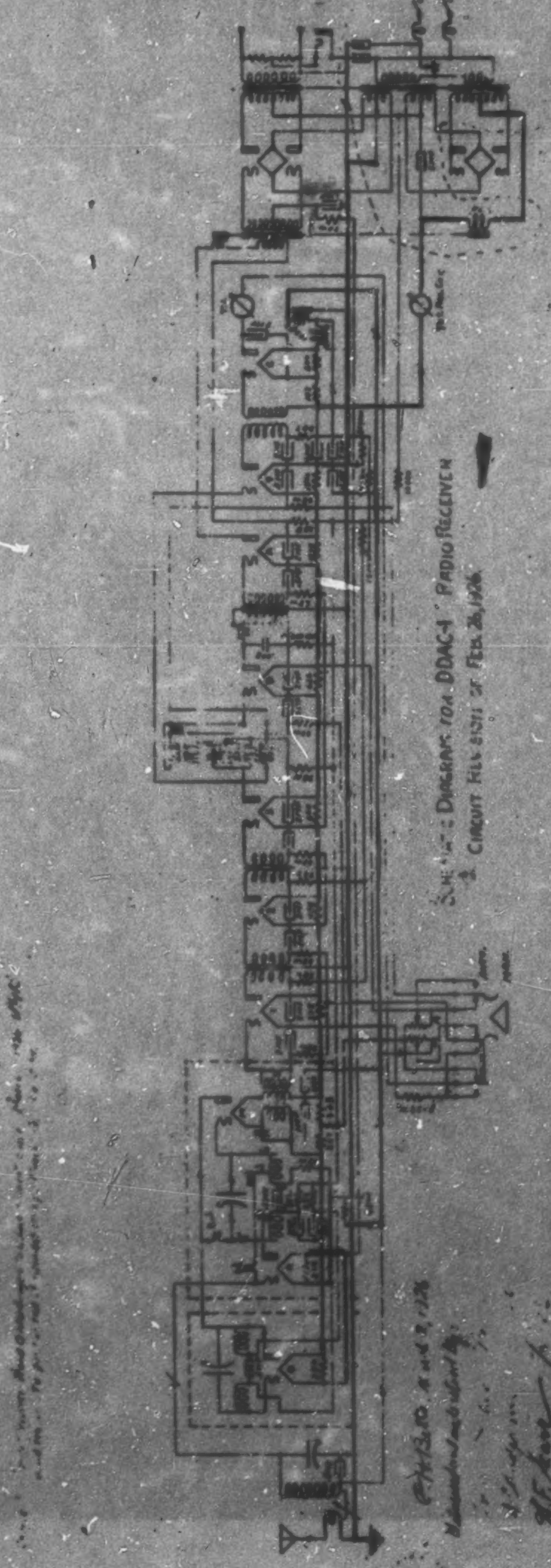

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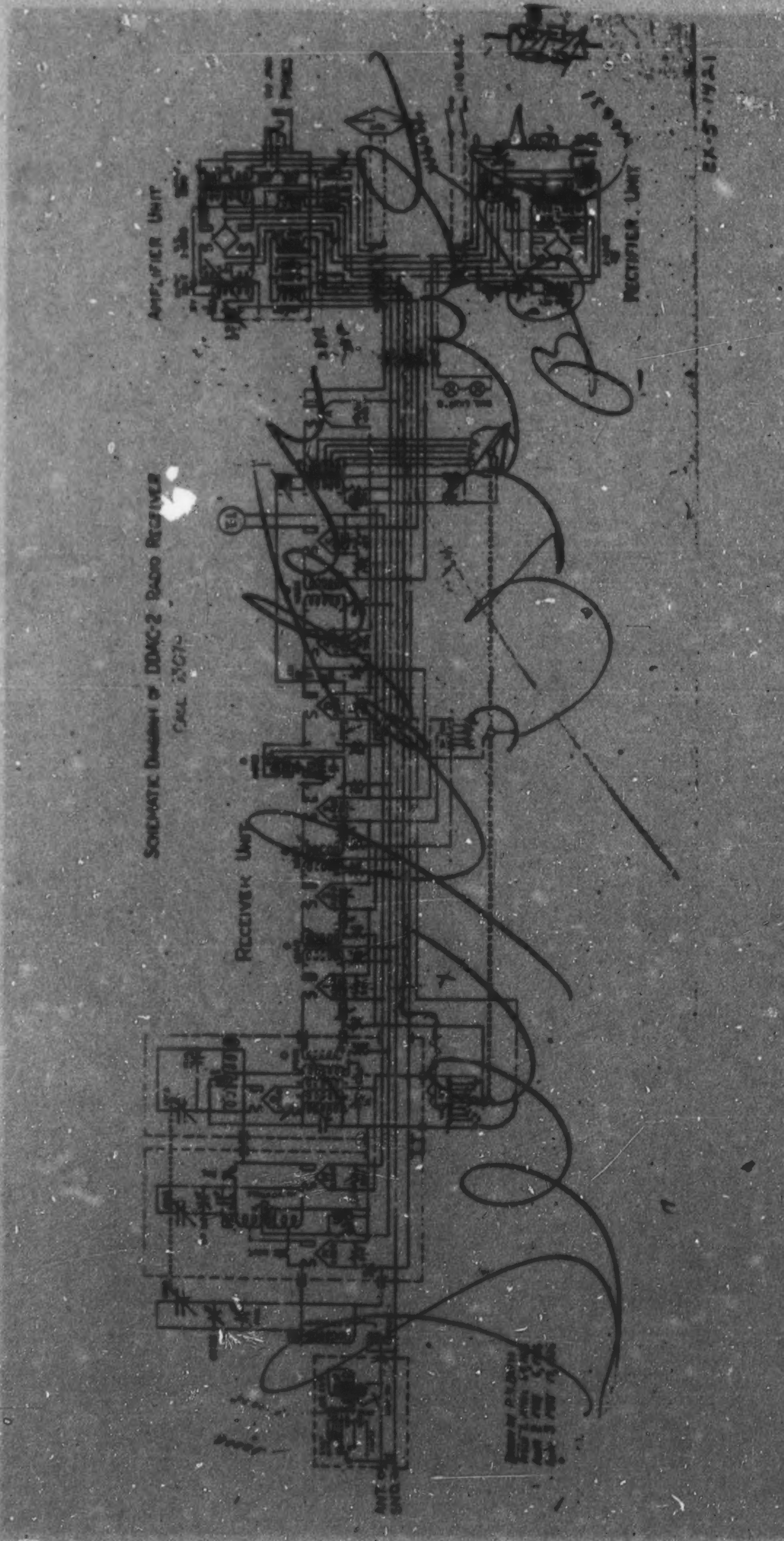

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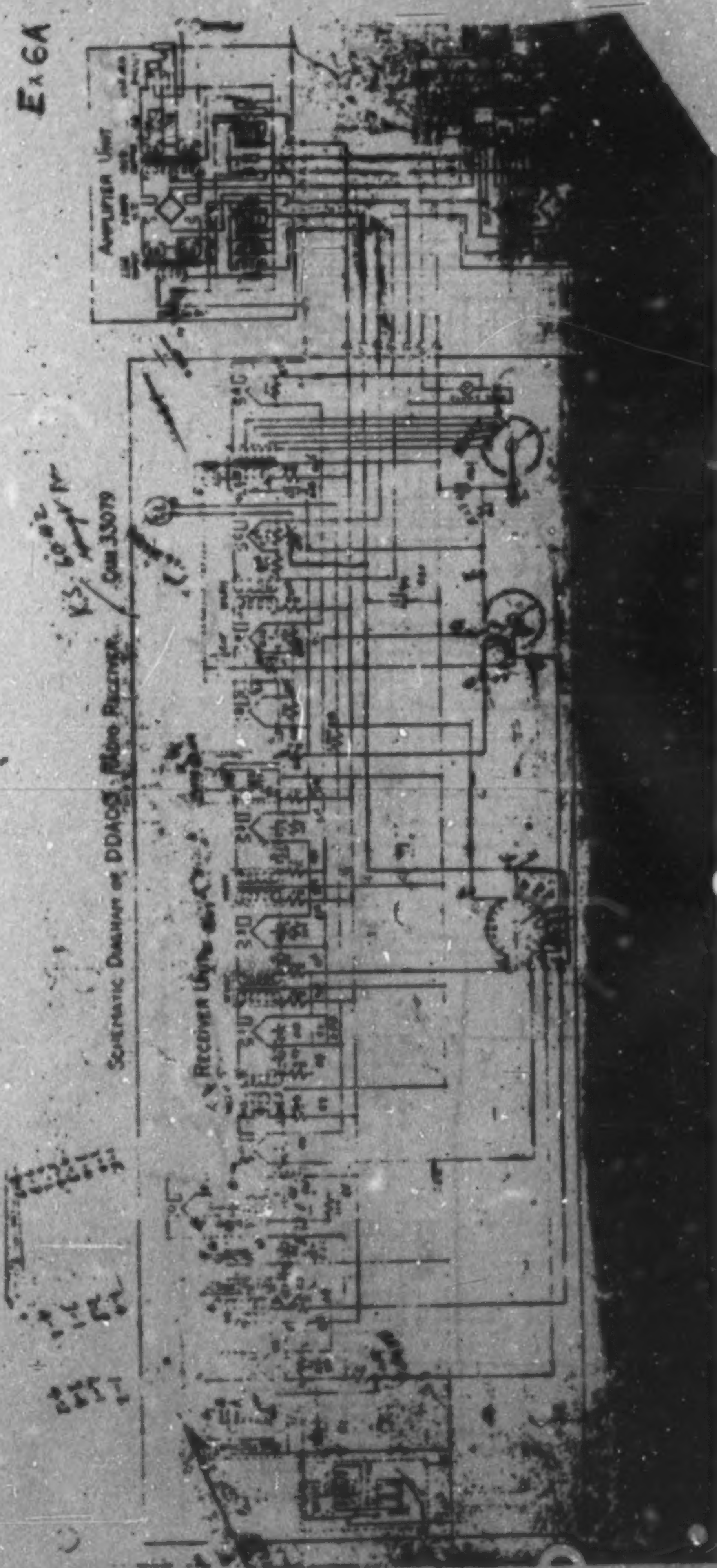

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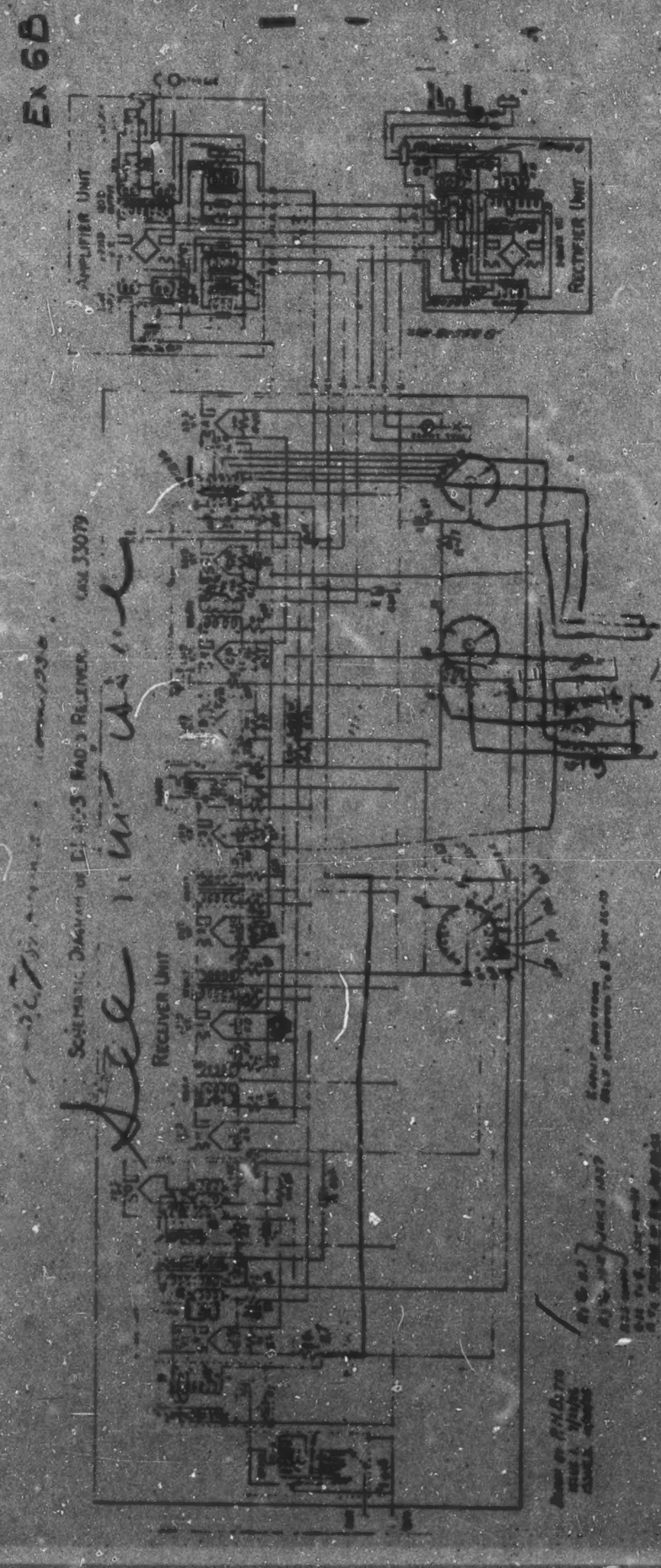

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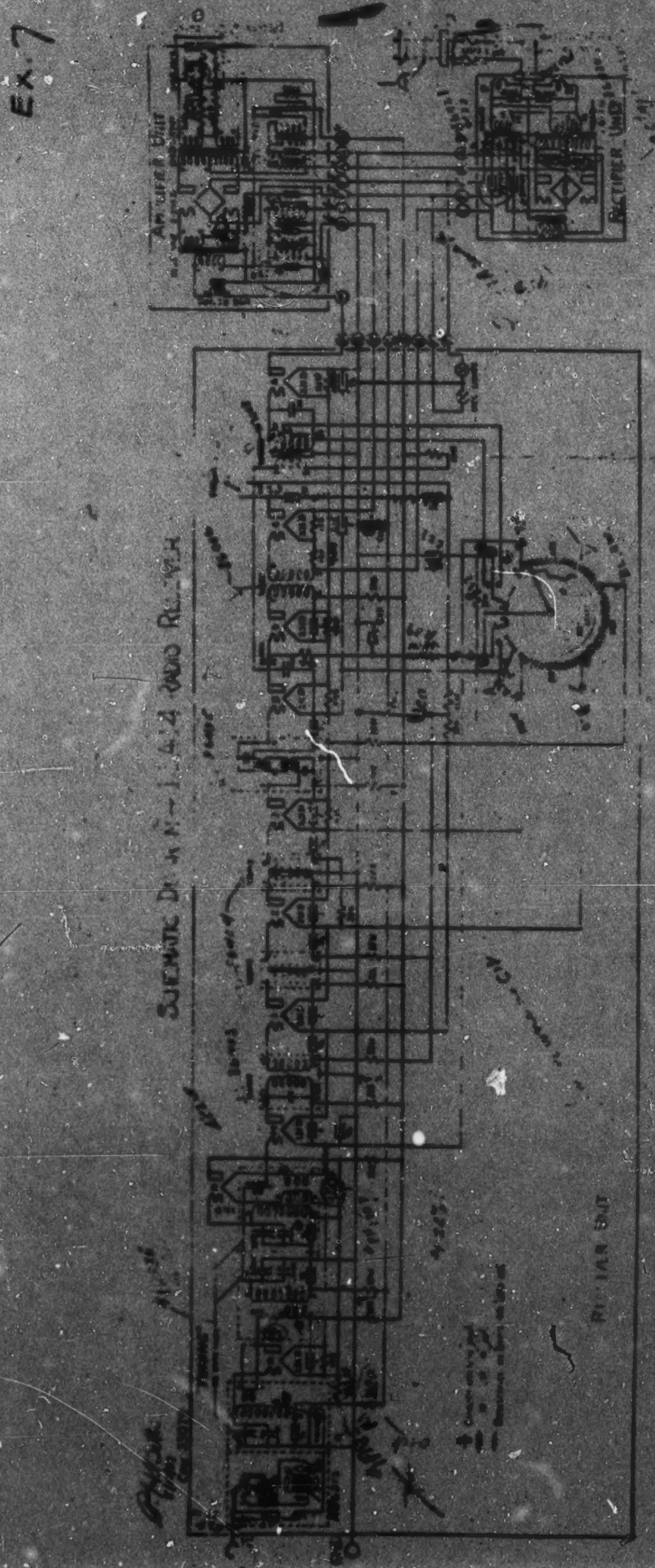

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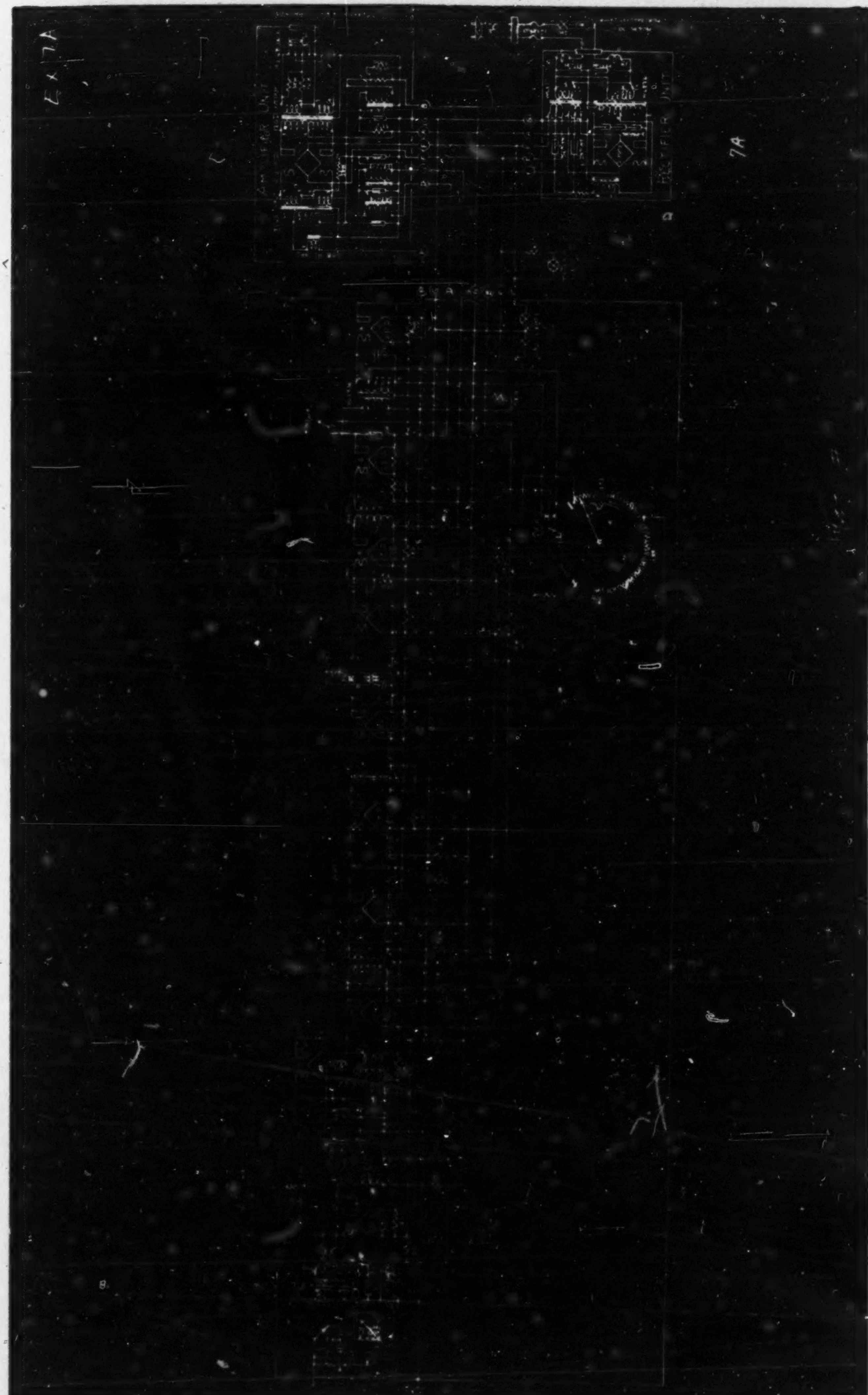

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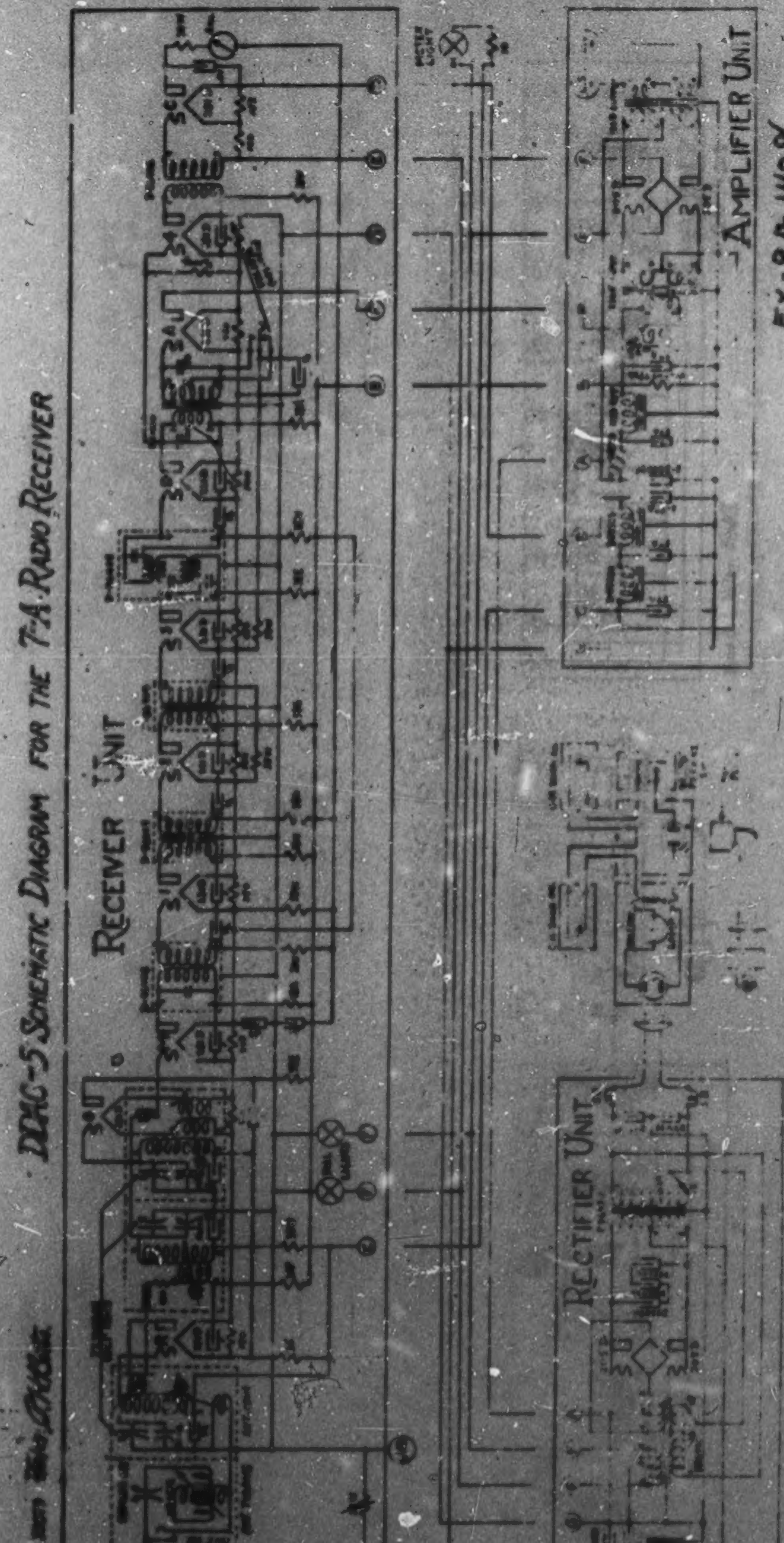

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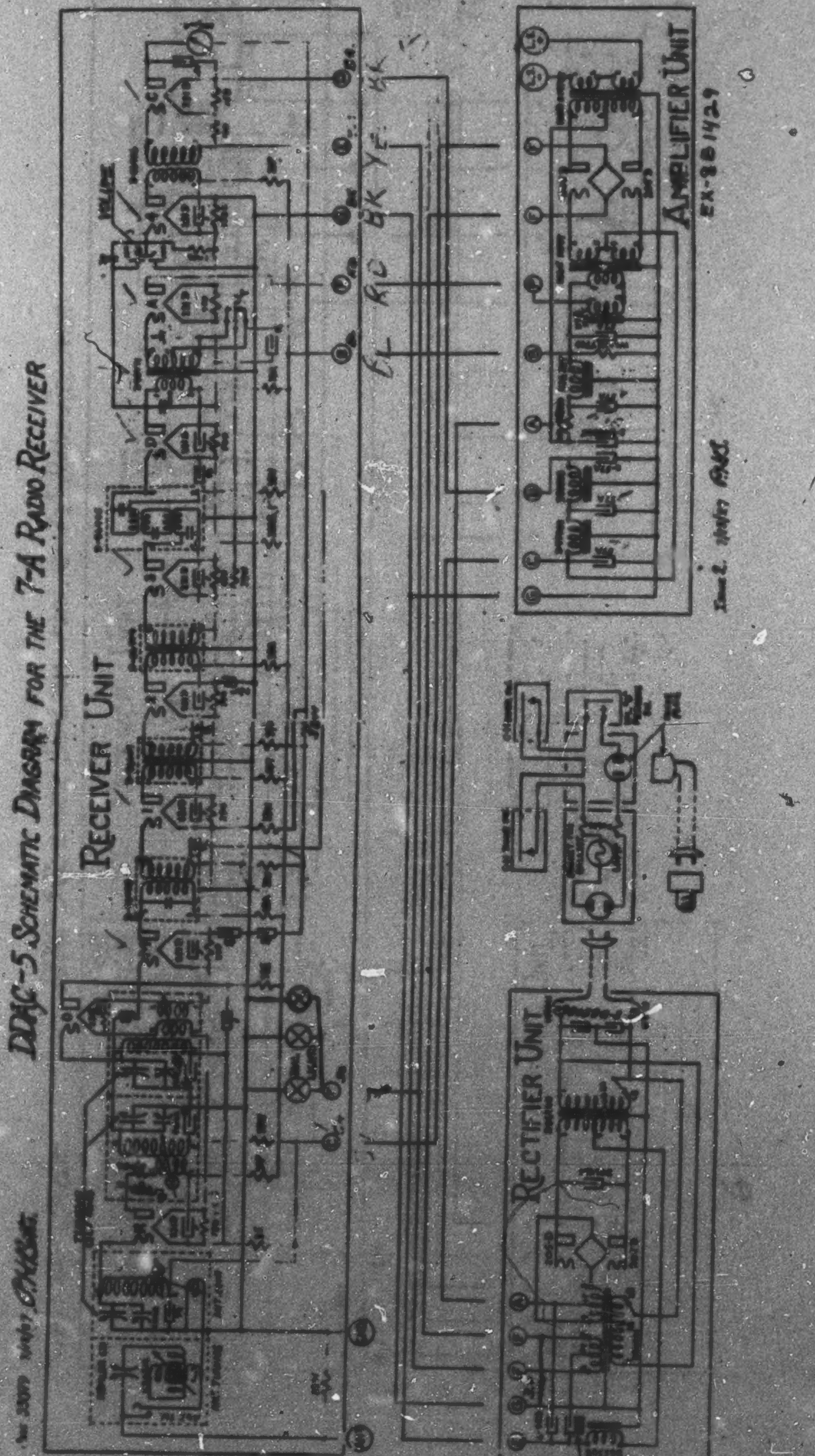

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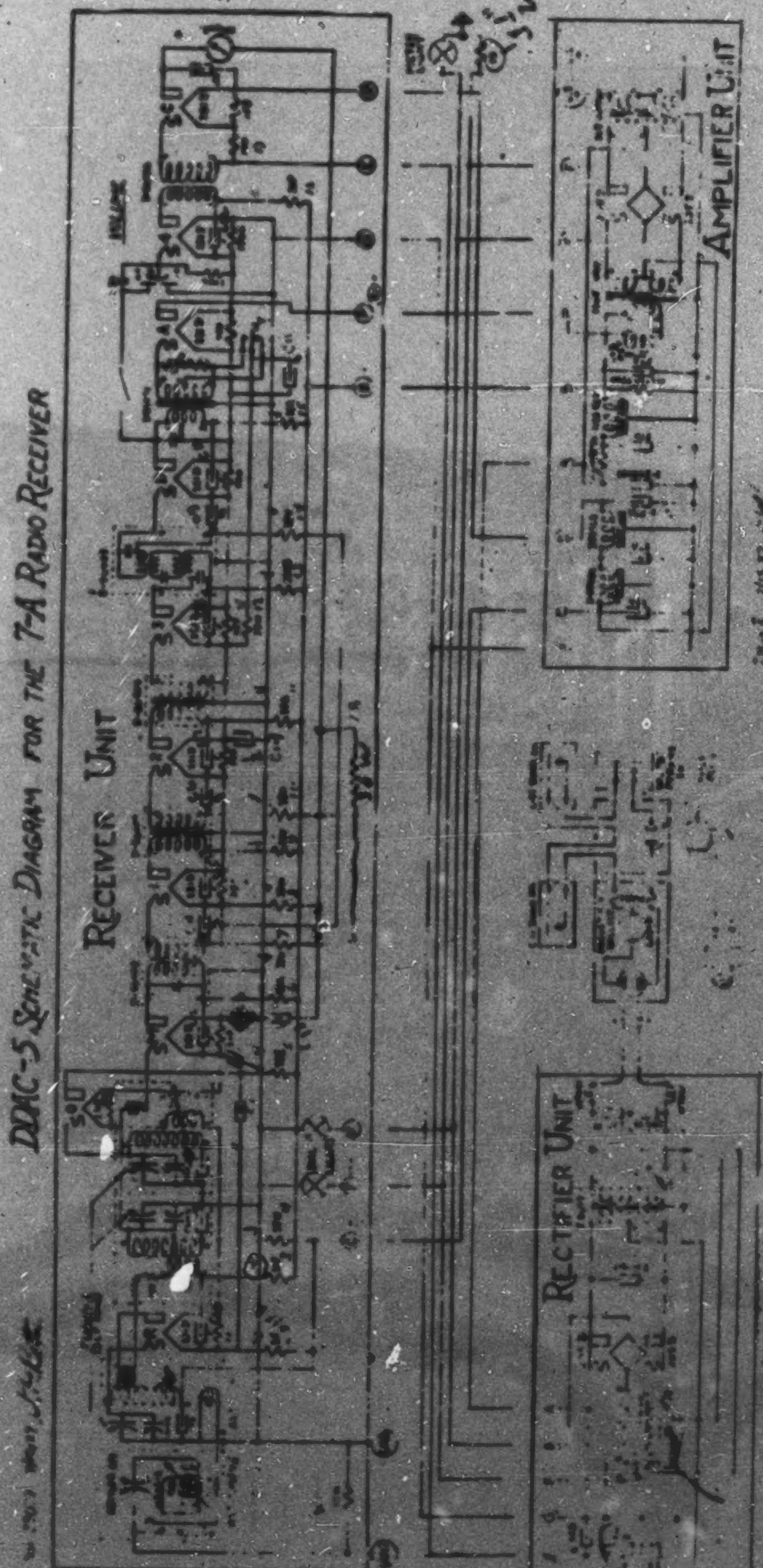

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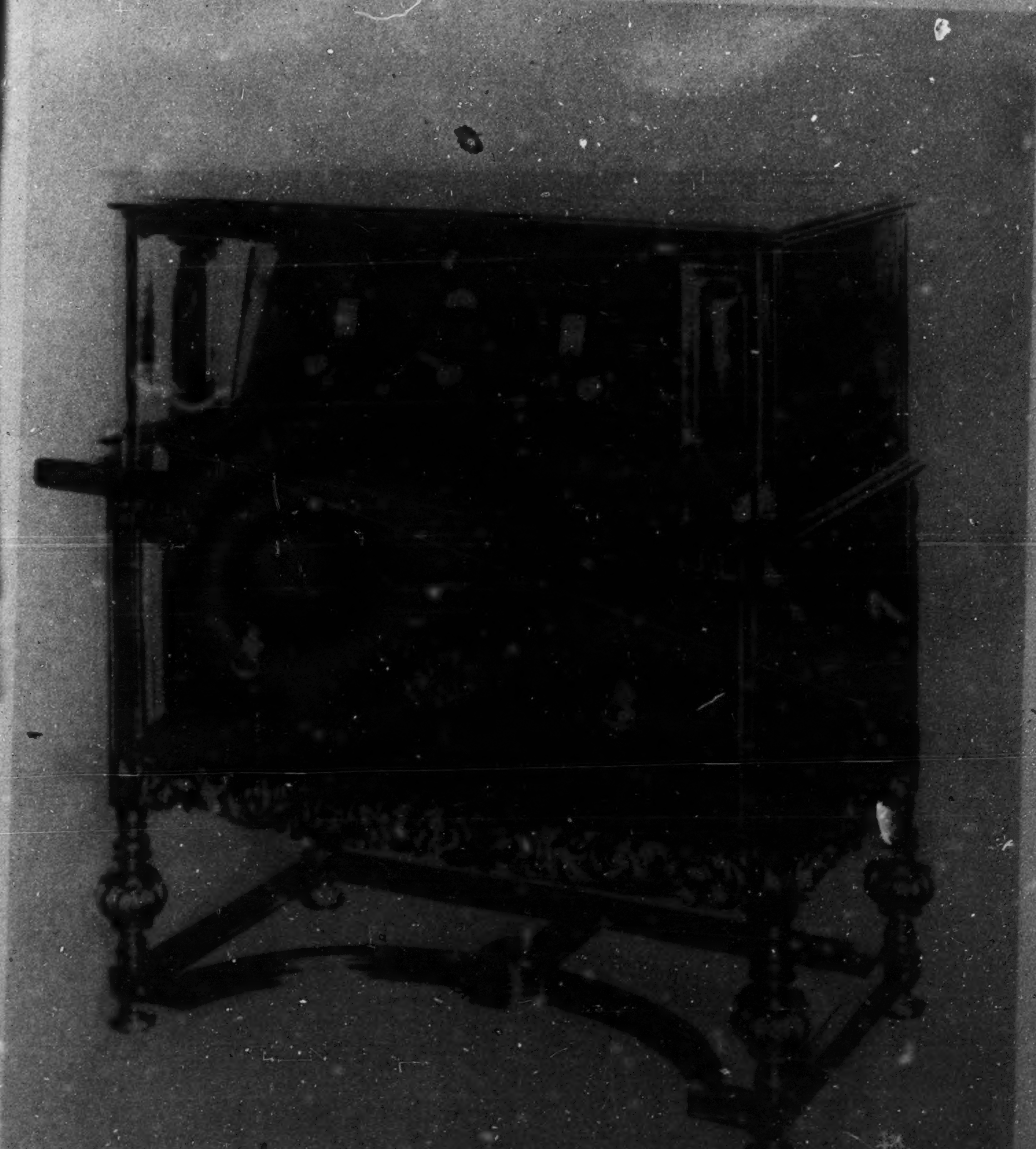

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PLAINTIFF'S EXHIBIT NO. 9-E
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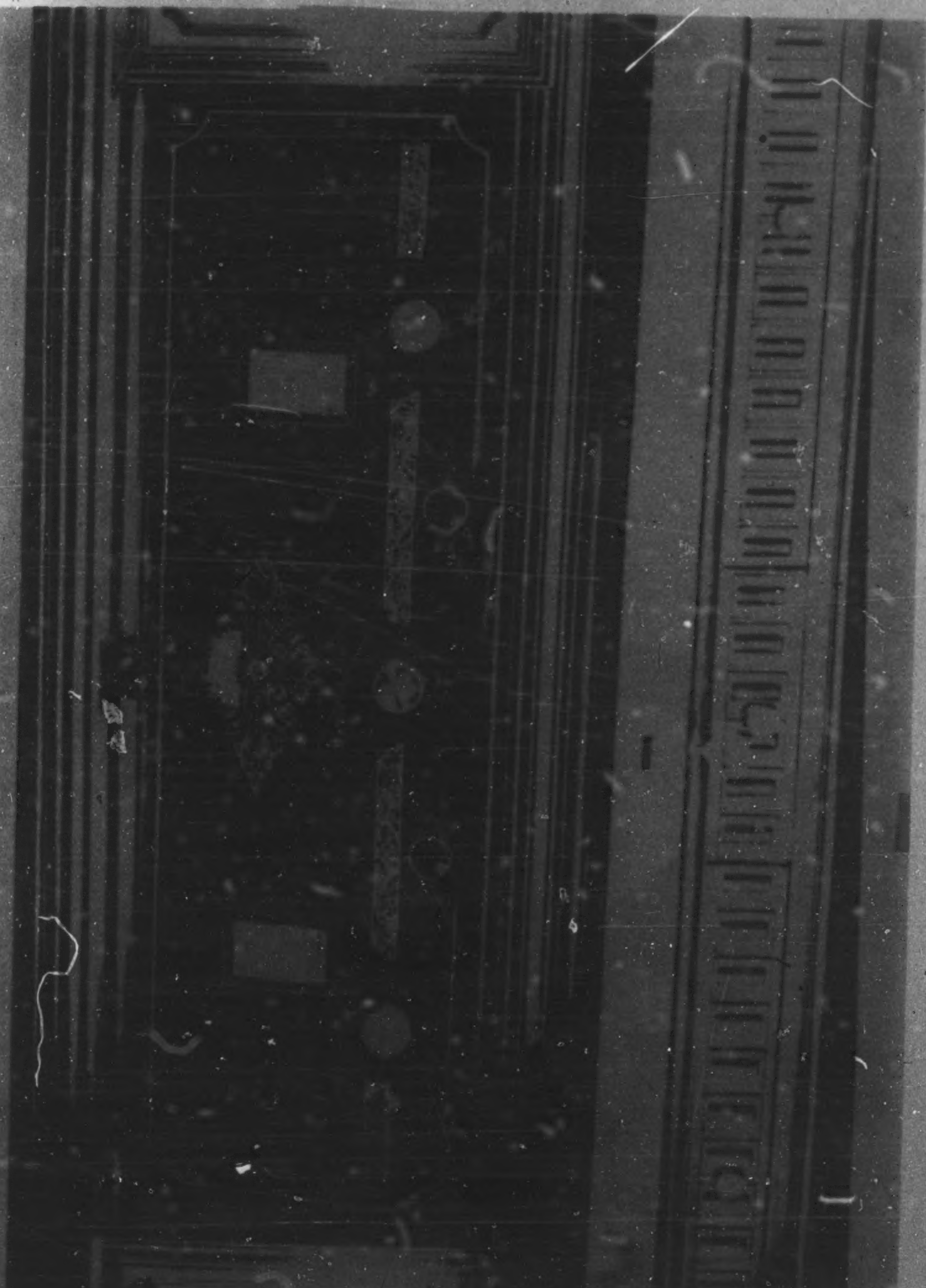

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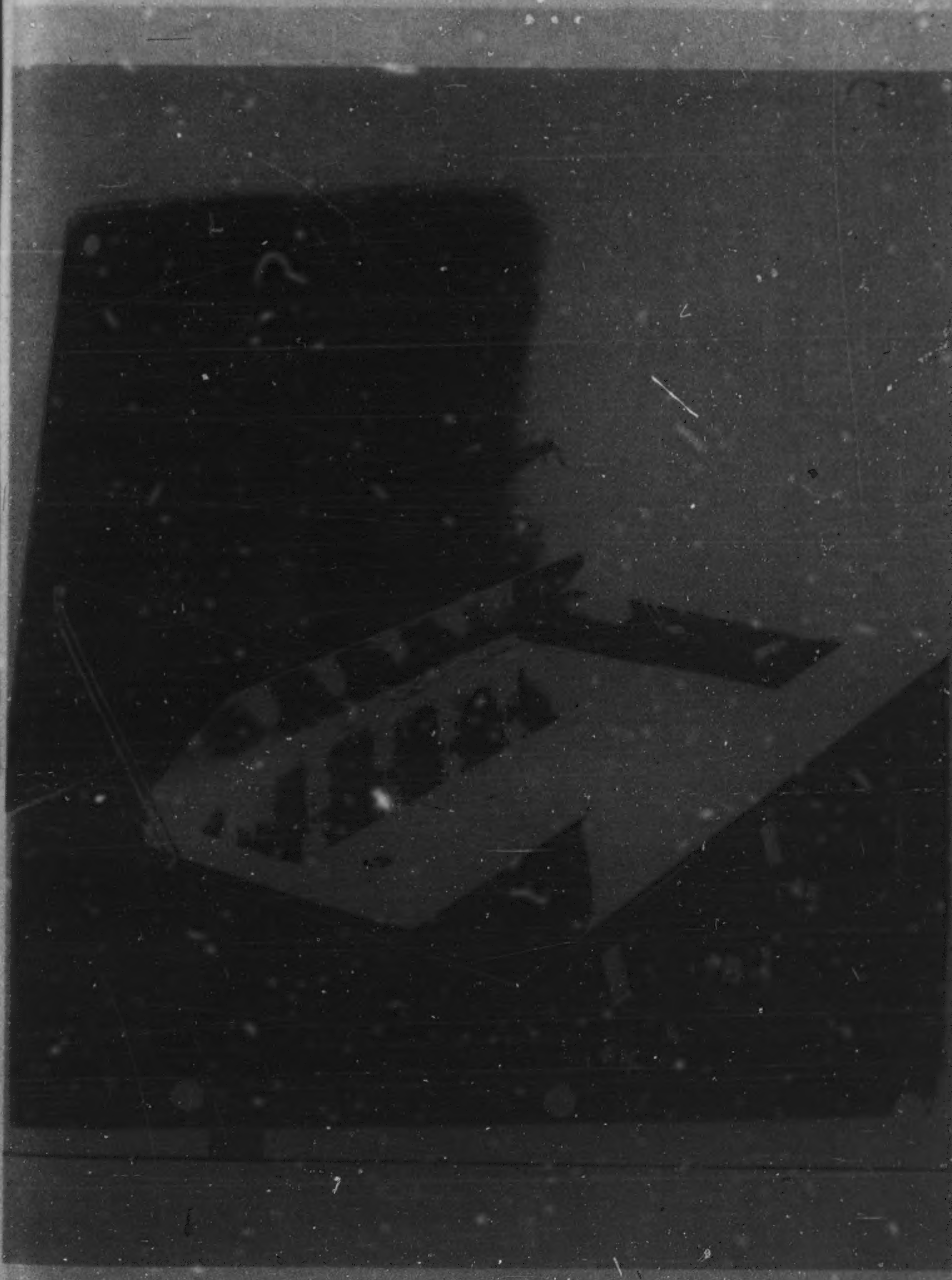

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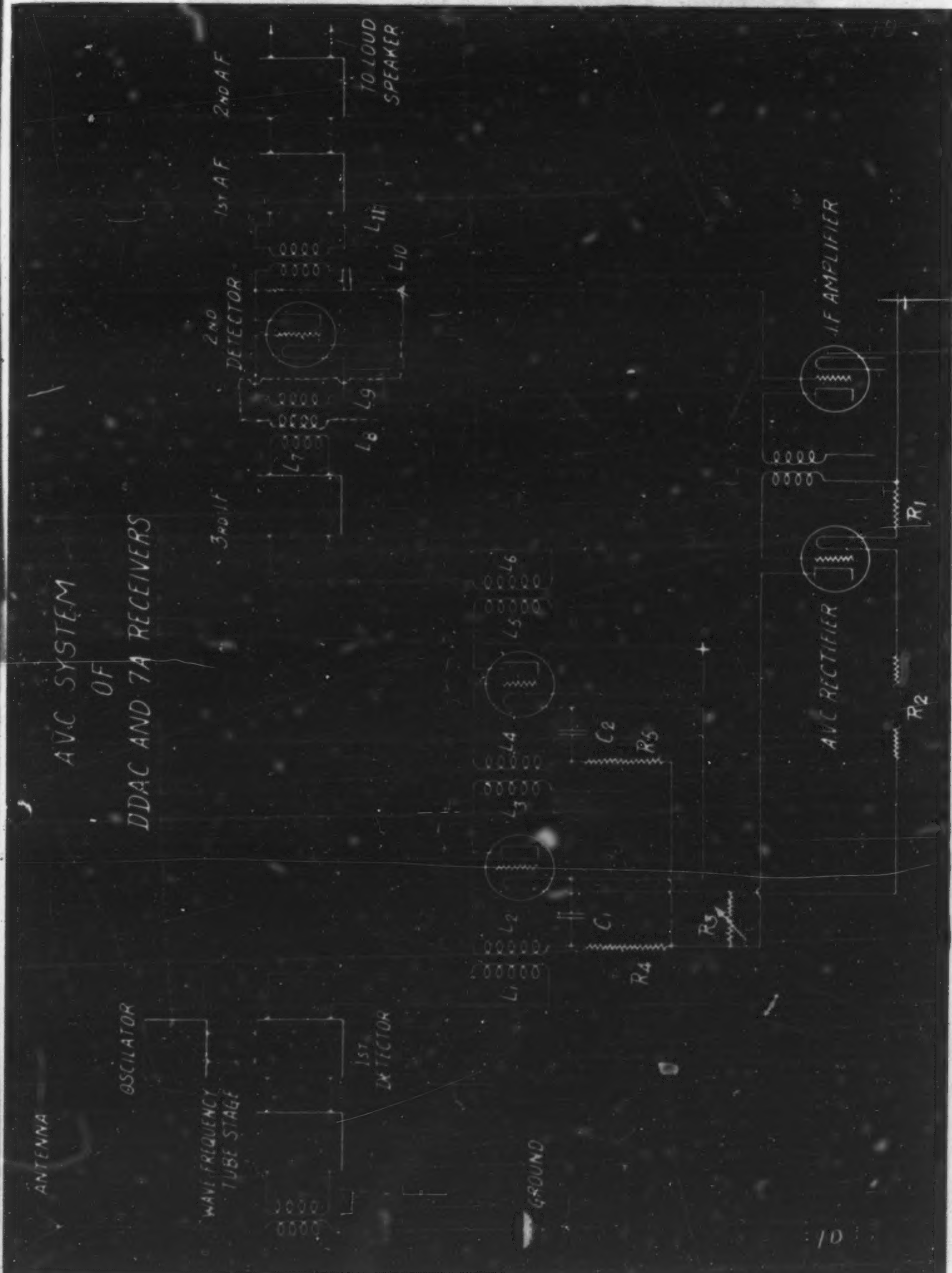

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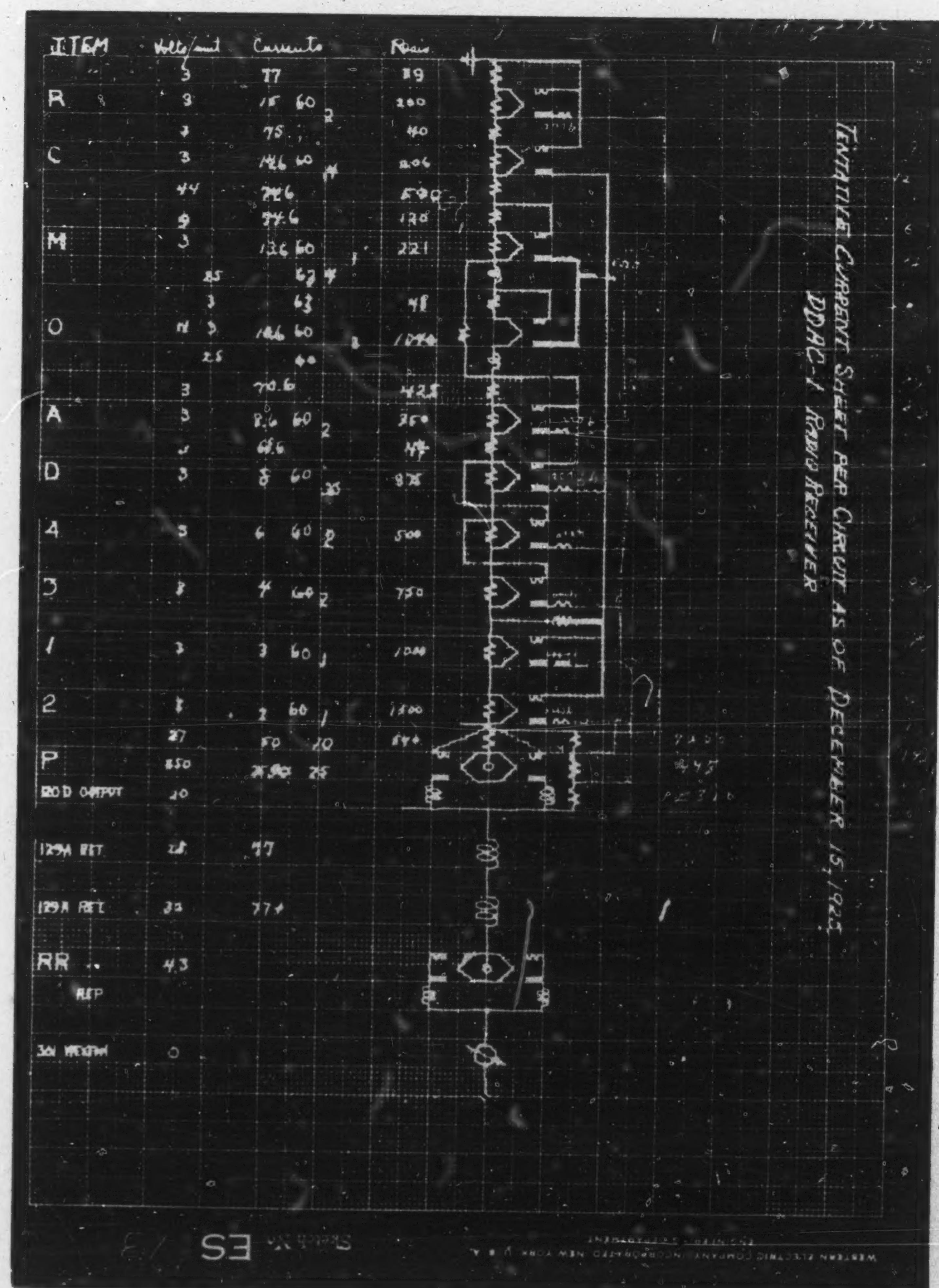

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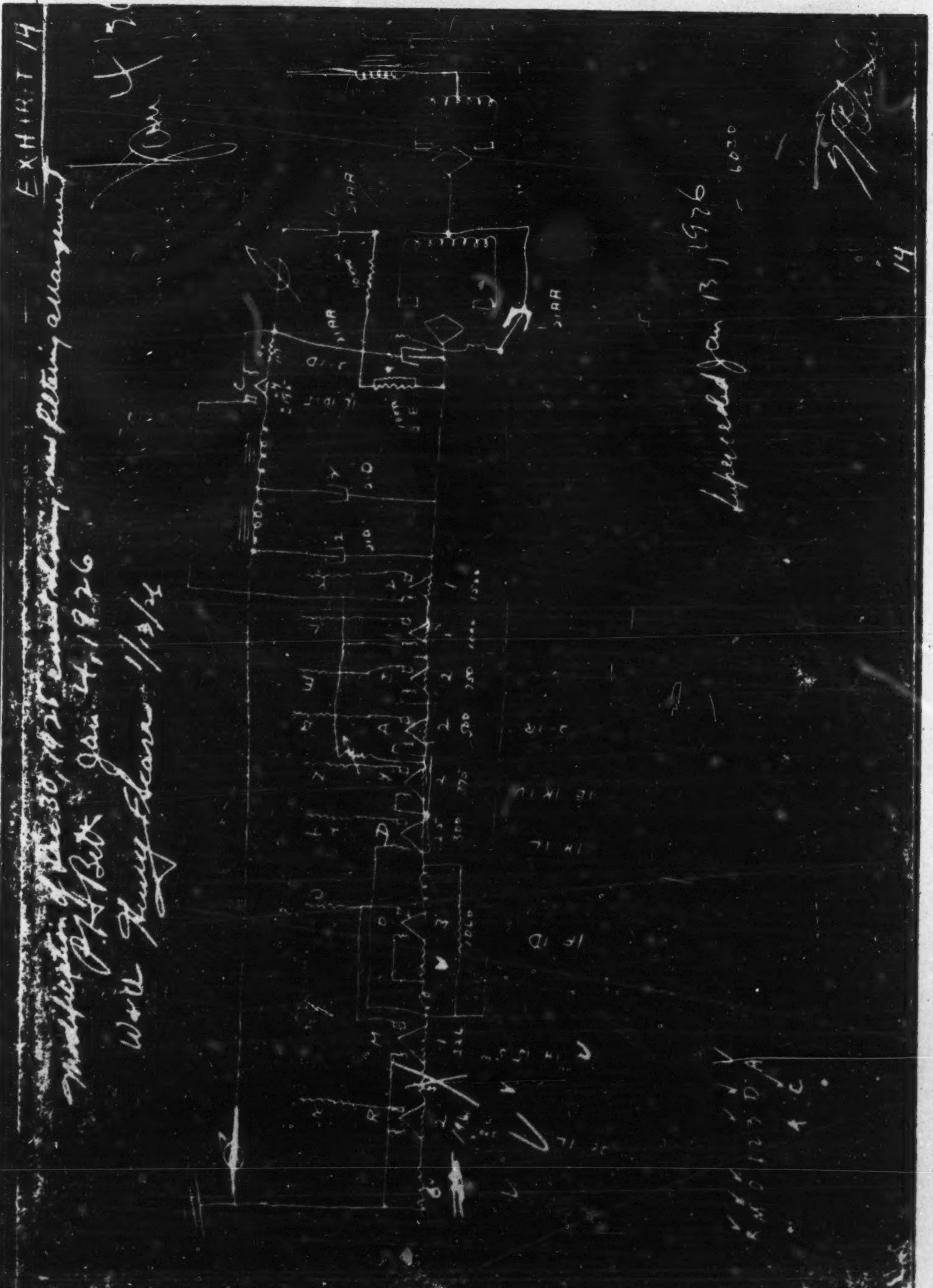

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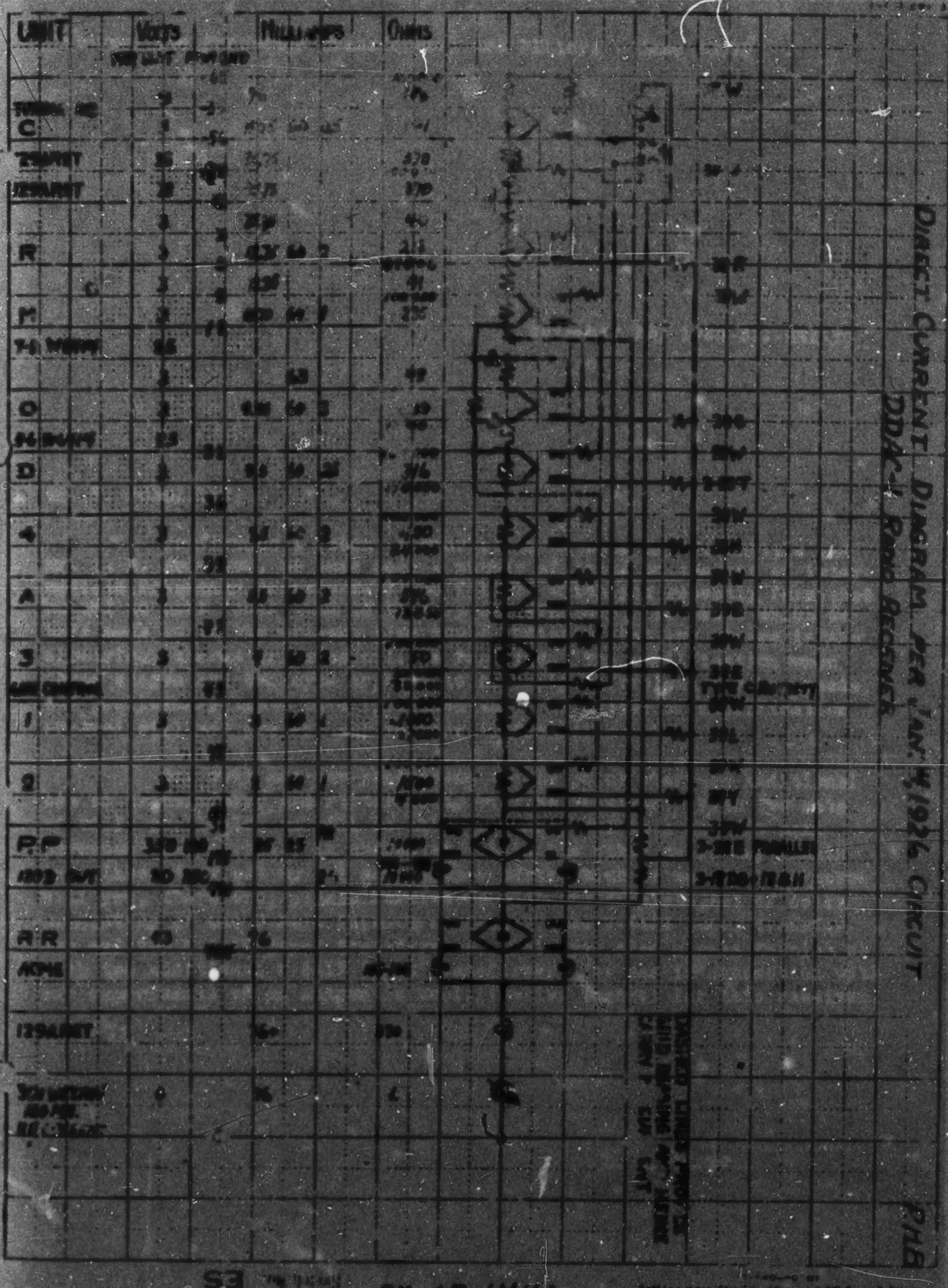

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PLAINTIFF'S EXHIBIT NO. 16
(accompanying Betts et al deposition--Pl. Ex. 28)

Intermediate Frequency Transformers and Filters - Case 32079

November 25, 1925-311-SEA-YQ

MR. W. FONDILLER,

Confirming a recent conversation between Mr. H. Whittle and Mr. S. E. Anderson, we have made a number of tests on the set of intermediate frequency transformers and filters which you recently furnished us and we have found them to be very satisfactory. No tests which we have made up to the present time would indicate that any change in the electrical characteristics will be required. The amplification when three stages are employed appears to be amply sufficient for our needs, and preliminary tests have indicated that the matter of amplification control will not present any serious difficulties.

Our work has now progressed to the point where an additional set of transformers and filter coils will be required. With two sets of coils available, we will be able to embody one in a circuit semi-permanent and portable in character, while the other coils may remain in a laboratory set-up for any further tests which we may wish to make. Will you, therefore, please furnish us with one complete set of coils consisting of one W-6414 Input Transformer; one W-6428 Input Transformer and two W-6417 Input Transformers. Will you also please furnish us with two additional W-6417 Input Transformers for use in connection with our experiments on an automatic amplification control for this receiver.

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O. M. GLUNT

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PLAINTIFF'S EXHIBIT NO. 17
(accompanying Betts et al deposition--Pl. Ex. 28)

Special Intermediate Frequency Transformer for Improved Double Detection Radio Receiver - Case 33079

January 22, 1926-311-SKA-XKE

MR. W. FONDILLER:

Confirming a conversation between Mr. A. J. Christopher and Mr. S. E. Anderson we desire to obtain a special intermediate frequency transformer for use in connection with the automatic amplification control which is to be employed in the laboratory model of the improved double detection radio receiver.

In cooperation with your department we have found that the grid circuit of the amplifying tube for the automatic amplification control may be connected to one of the primary windings of the final filter coil in the intermediate frequency amplifier without affecting the characteristics of this filter. We are now using a special coil furnished by your department as the coupling transformer between the amplifier and the control rectifier. This coil has been found to be fairly satisfactory for this purpose. It has a voltage step-up of approximately 3 at 83 kilocycles and the resonance characteristic is comparatively sharp. There is also an additional peak of approximately 1.5 at about 92 kilocycles. While this latter peak does not interfere with the operation of this coil in connection with the automatic amplification control because the amplification of the filter is very low at this frequency it will be desirable to eliminate it as far as possible in the final coil.

The desired characteristics of this coil may be summarized as follows:

(1) The coil will be used between a 230-D vacuum tube operating as an amplifier with approximately 2 milliamperes space current and a 230-D vacuum tube operating as a negative grid bias type rectifier.

(2) The voltage step-up should be as high as possible at 83 kilocycles.

(3) The voltage amplification at 82 and 84 kilocycles should be less than that at 83 kilocycles altho it is not essential that an excessively sharp characteristic be obtained.

(4) The voltage amplification at all other frequencies should be as low as possible.

(5) These characteristics should preferably be obtained in a coil of as simple a type as possible having no external tuning capacities other than the usual small one across the secondary for adjustment.

Will you please furnish us with a sample coil conforming in general to these characteristics. The cost of this coil may be charged to case 33079.

Sla

O. M. CLUNT

LA

PLAINTIFF'S EXHIBIT NO. 18
(accompanying Betts et al deposition--Pl. Ex. 28)

31

DATE Nov 16, 1925

[illegible] #1

C	Mils	ohms	volts		volts	amp	
8							
12							
14							
92	1	0.1		14	.68	6[illegible]	
90	1	0.1		28	1	9000	
68	1	0.1	1	40	[illegible]	[illegible]	
[illegible]	1	0.1	.0001	50	1.29	12900	
[illegible]	1	0.1	[illegible]	5[illegible]	1.41	14100	
	1	0.1	.0001	56	1.38	13800	
[illegible]	1	0.1	.0001	51	1.31	13100	
[illegible]	1	0.1	.0001	62	1.46	14600	
[illegible]	1	0.1	.0001	37	[illegible]	[illegible]	
24	1	0.1	.001	8	[illegible]	[illegible]	
12							
6							
4							
2							
0							
18							

HR

Curve carried over greater range on pp 32-33

32

DATE

Test Freq. quar. & lat. Modu. ø/

3 stages Test
Input to Modulator — with Res box

DATE Nov. 23, 1925

Amplification Control by varying V_{I_1}

Input at 83 KC

48

DATE Nov. 27, 1925

Amps VS - Grid Bias I_2

I_2 balanced.

At 84 KC

Impossible to prevent singing around I_2 - then balancing capacity in I_2

H.S.

50

DATE Nov 28, 1930

ampl vs Sense – [illegible]

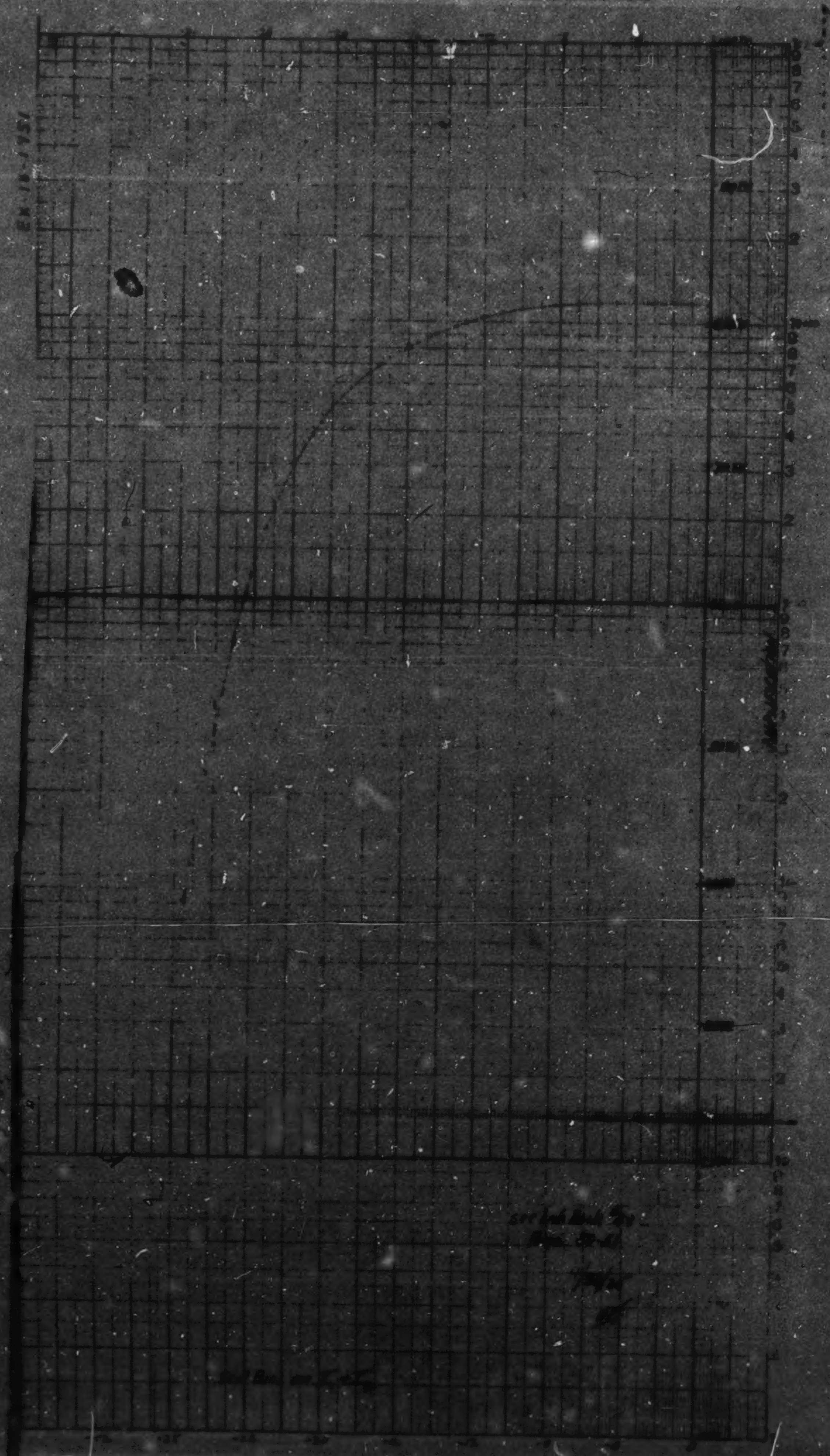
[illegible] 10J-5 1054

.3	7
.4	15
.5	25
.6	36
.7	39
.8	63
.9	80
1.0	98
1.1	117
1.2	137
1.3	126
1.4	161
1.5	205
1.6	232

P. 51

DATE Nov 28, 1923

[illegible]	[illegible]	volts	Def	Volts	[illegible]	[illegible]	[illegible]	volts	Def	Volts	[illegible]
-30	5	.005	0	0	0	30	1/1000	10	30	0	0
-27.5	5	"	2	0.3	60	29.5	1/1000	10	0	0	0
-27	5	"	9	0.55	110	29	1/1000	10	2	.3	203
-26.5	5	"	28	0.94	188	28.5	1/100	0.1	16	1.70	7
-26	5	"	63	1.48	296	28	1/50	.005	50	1.30	26
-25.5	5	"	155	2.36	472	27.5	1/20	.002	80	1.67	83
-25	3	.003	127	2.13	710	27	1/10	.001	70	1.56	166
-24.5	1	.001	33	1.03	1030	26.5	1/5	.005	42	1.17	234
-24	1	"	55	1.36	1360	26.	1/5	.005	120	2.06	412
-23.5	1	"	87	1.75	1750						
23	1	"	136	2.20	2200						
-22.5	1	"	178	2.54	2540		Mils 0.2 [illegible]				
22	.5	.0005	63	1.44	2960	22	1.5	.0003	26	.91	3033
-21.5	.5	"	83	1.70	3400	21.5	1.5	"	36	1.08	3600
-21	.5	"	103	1.91	3820	21	1.5	"	45	1.22	4066
-20.5	.5	"	123	2.11	4220	20.5	1.5	"	55	1.36	4533
20.	.5	"	144	2.27	4540	20	1.5	"	64	1.49	4966
19.5	.5	"	168	2.46	4920	19.5	1.5	"	74	1.60	5333
19	.4	.0004	130	2.06	5150	19	1	.0002	40	1.14	5700
18.5	.4	"	136	2.20	5500	18.5	1	"	46	1.23	6150
18	.4	"	150	2.32	5800	18	1	"	51	1.31	6550
17.5	.4	"	172	2.50	6250	17.5	1	"	57	1.39	6950
17	.4	"	180	2.56	6400	17	1	"	63	1.48	7400
						16.5	1	"	70	1.56	7800
						16	1	"	75	1.62	8100
						15.5	1	"	80	1.67	8350
						15	1	"	[illegible]	1.77	8850
	Mils 0.2 [illegible]					14.5	1	"	[illegible]	1.82	9100
7	1	.0002	152	2.34	11 700	14	1	"	98	1.86	9300
6	1	"	153	2.35	11 750	13.5	1	"	105	1.93	9650
5	1	"	158	2.38	11 900	13.	1	"	109	1.97	9850
4	1	"	158	2.38	11 900	12.5	1	"	114	2.01	10050
3	1	"	158	2.38	11 900	12	1	"	120	2.06	10300
2	1	"	158	2.38	11 900	11	1	"	129	2.14	10700
1	1	"	156	2.37	11 850	10	1	"	139	2.23	11150
0	1	"	154	2.36	11 800	9	1	"	142	2.25	11250
						8	1	"	146	2.29	11450

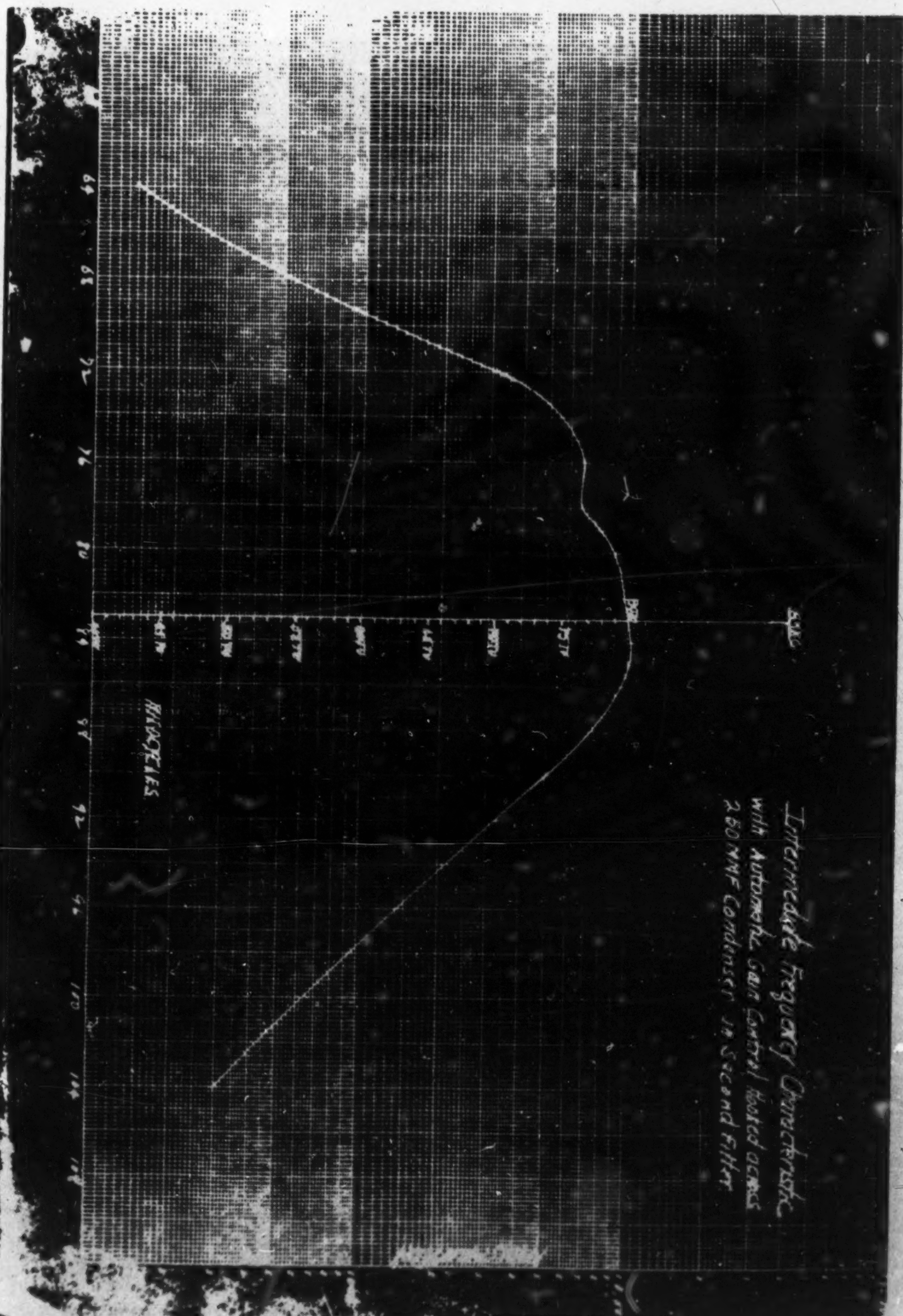


54

DATE 12/2/25

Int freq characteristic

With automatic Gain control used
across 250 MMF Condenser in Second
filter but not delivering -C to I_1 + I_2
Bias on I_1 + I_2 maintained constant
at - 6 Volts.



Intermediate Frequency Characteristic
with Automatic Gain Control Hooked across
280 MMF Condenser in Second Filter
KILOCYCLES
64
68
72
76
80
84
88
92
96
100
104
108

70

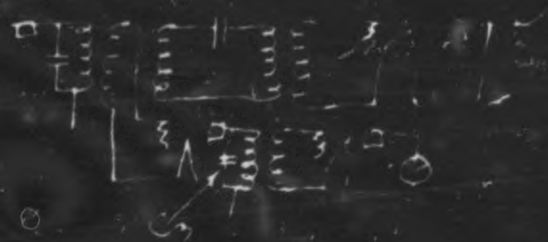
DATE 12/9/25

[illegible]

[illegible] 20 MM [illegible]

DATE 12/11/22

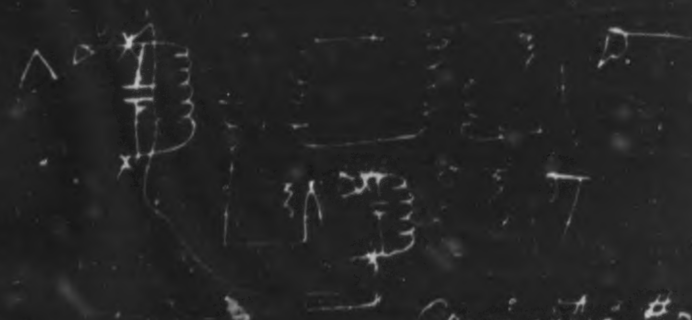
Investigation [illegible] Control
[illegible]



-.6 V on [illegible]
-13 V on [illegible]

[illegible]	Mils	Change I_g ½ MV input	Change I_g 1 MV input
[illegible]	1	.026	0.100
		.049	0.189
		.093	.37
		.200	.71
		.41	1.06
		.68	1.17
		.82	1.20
		.82	1.21
		.90	1.22
		.98	1.25
		1.03	1.28
		1.04	1.28
		.94	1.30
		.46	1.15
		.92	.80
		[illegible]	.39
		.048	.170
		.026	.070

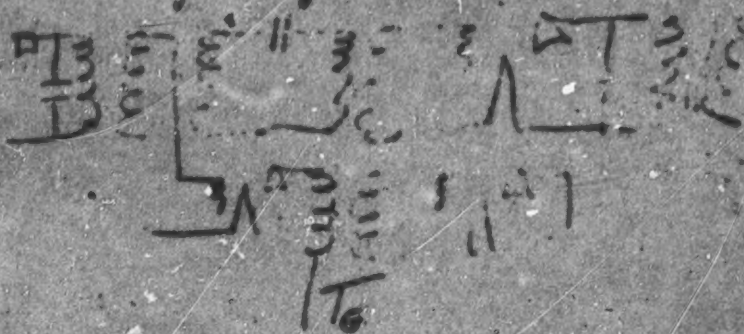
Connection #1



Connection #2

DATE 12/12/25

Continued fm Pg 84 + 85



Page [illegible]

Date

Close Coupling of T[illegible]

KC	M.H.	$\frac{I}{I_0}$ Ma.	$\frac{I}{I_0}$ Ma.	$\frac{I}{I_0}$ Ma.
96	0.1	.028		
94		.048		
92		.072		
91		.100		
90		.124		
89		.077		
88		.090		
87		.075		
86.5		.084		
86		.118	.30	.190
85.5		.156	.42	.26
85		.25	.66	.41
84.5		.34	.92	.52
84		.50	.96	.56
83.5		.73	.98	.56
83		.92	.98	.56
82.5		.96	.77	.54
82		.97	.92	.52
81.5		.97	.80	.48
81		.96	.58	.34
80.5		.93	.40	.23
80		.75	.28	.18
79.5		.52		
79		.37		
78.5		.25		
78		.20		
77		.141		
76		.116		
74		.063		
72		.024		

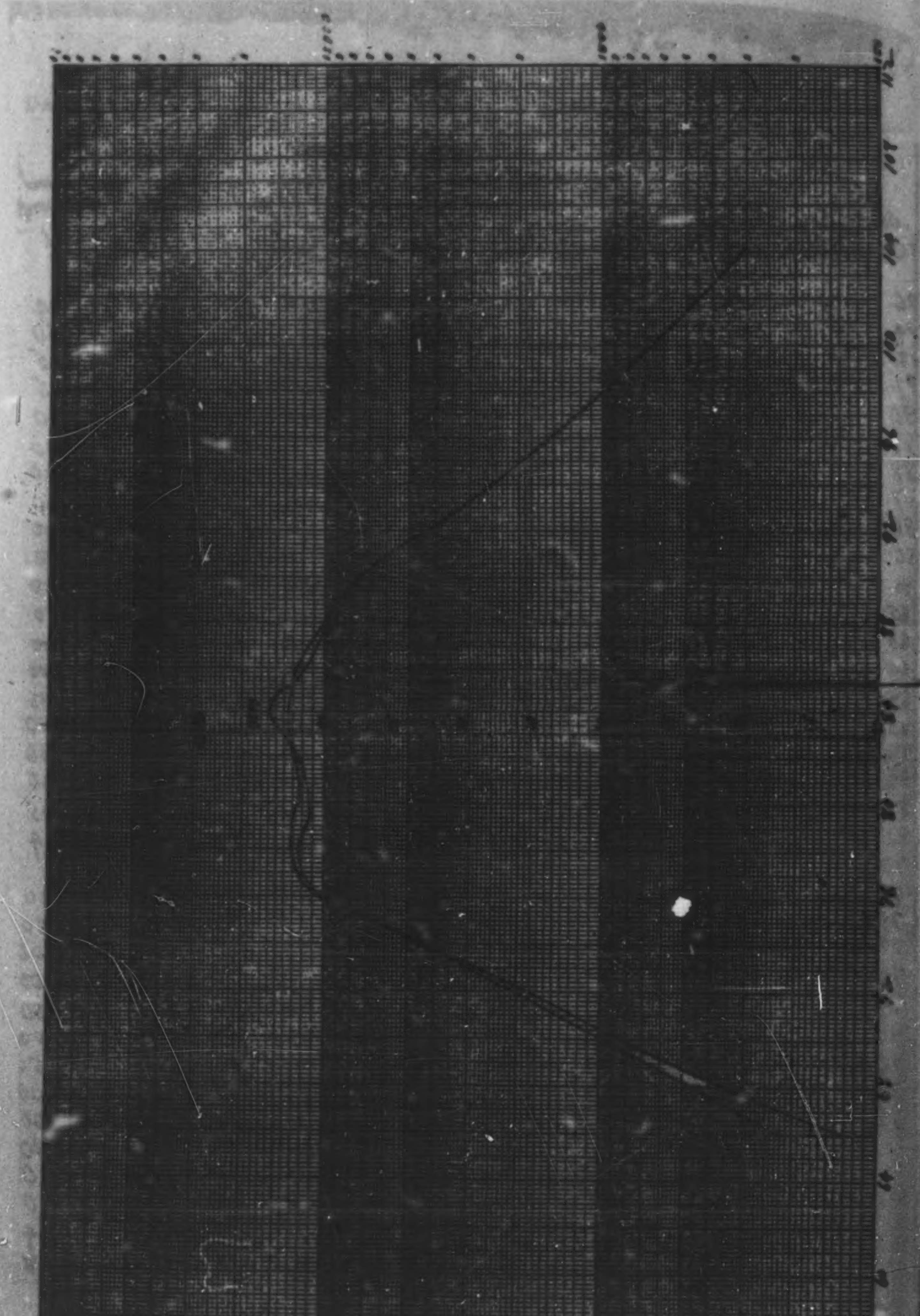
Replaced coupling to Trans. Secondary

Added 30000 Ω Plate Bank

Quality Curve (326 Dandee with 1000 [illegible])

KC	Input Mils	Input ohms	Input volts	Out Def	Out volts	Amplif
104	1	5	.005	71	1.57	314
102	1	5	"	142	2.25	450
100	1	2	.002	50	1.29	645
98	1	2	"	110	1.97	985
96	1	1	.001	62	1.46	1460
94	1	1	"	163	2.42	2420
92	1	0.5	.0005	129	2.14	4280
90	1	0.2	.0002	54	1.49	7450
88	1	0.2	"	112	2.00	10000
86	1	0.2	"	155	2.36	11800
84	1	0.1	.0001	71	1.51	15700
82	1	0.1	"	50	1.29	12900
80	1	0.1	"	46	1.23	12300
78	1	0.1	"	52	1.32	13200
76	1	0.1	"	32	1.02	10200
74	1	0.2	.0002	24	.87	4350
72	1	0.5	.0005	28	.94	1880
70	1	1	.001	22	.84	840
68	1	2	.002	24	.87	435
66	1	5	.005	38	1.12	124
92	1	0.2	.0002	23	.85	4250
90	1	0.2	"	62	1.46	7300
88	1	0.2	"	110	1.97	9850
86	1	0.2	"	150	2.32	11600
84	1	0.2	"	197	2.69	13450
82	1	0.2	"	178	2.54	12700
80	1	0.2	"	149	2.27	11350
78	1	0.2	"	164	2.49	12200
76	1	0.2	"	104	1.92	9600
74	1	0.5	.0005	140	2.34	4480
72	1	1	.001	114	2.01	2010
70	1	2	.002	94	1.82	910
68	1	5	.005	150	2.32	464
66	1	5	.005	40	1.19	228

Det #4 used
for Gain Cont. Rect.
f.l. calibration See Pg 88



104

DATE 2/17/21

[illegible]

[illegible]

Calibration 20 J Thermo [illegible]
\# - 1134 (Meter # 578)

.5 Mil	= 32
1	118
1.5	= 244

Calibration 20 D Thermo [illegible]
\# 2369 ([illegible] # 578)

2 Mils	29
3 Mils	63
4 Mils	15
5 Mils	63

Calibration Def tube #102

[illegible]	Mils	Def
		102
100	.5	9
150	.75	22
200	1.0	36
250	1.25	57
300	1.50	77
350	1.75	100
400	2.00	136
450	2.25	170
[illegible]	[illegible]	193

DATE [illegible] [illegible] June 14/1926 P.H.B.

Set up per [illegible] VAC for [illegible] stage, ~~and~~ circuit per [illegible] 3 with added condensers as follows: 1 mf − M to G, and ½ mf + 1 to G

Neg C on 1–2 measured from −M. Actual C = −3 v on 1, −6 v on 2.

Volts	I am	at 84 KC Total volts	
0	9310	3	
.36	9000	3.36	
1.80	8	4.80	
2.84	7	5.84	
3.73	6	6.73	
4.47	5	7.47	
5.18	4	8.18	
5.95	3	8.95	
6.77	2	9.77	
7.47	1,300	10.47	
7.93	1000	10.93	
7.93	10-100	10.93	
8.21	800	11.21	
8.58	600	11.58	
8.81	500	11.81	
9.04	400	12.04	
9.39	300	12.39	
9.87	200	12.87	
10.13	160	13.13	Click
add 4.47 volts,			
5.65	160	13.12	
5.91	130	13.38	
6.24	100	13.71	
6.36	90	13.83	
6.57	75	14.04	
6.86	62	14.33	
7.00	51	14.47	
7.17	42	14.64	
7.32	35	14.79	
7.51	29	14.98	
7.6[illegible]	27	15.11	
7.78	20	15.25	

Volts	I am	Total C
7.88	18	15.35
7.90	16.5	15.37
7.96	—	15.43
8.03	15	15.50
8.25	12	15.72
8.46	10	15.93
8.62	9	16.09
8.83	8	16.30
9.12	7	16.59
9.57	6	17.04
10.12	5	17.59
add 9 volts		
5.63	5	17.63
6.50	4	18.50
7.88	3	19.88
9.11	2.5	21.11

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STIPULATION AS TO RECORD ON APPEAL UNDER RULE 75 (f) OF THE RULES OF CIVIL PROCEDURE

(Filed February 20, 1940)

It Is Hereby Stipulated between counsel for the parties hereto that the following parts of the record, proceedings, and evidence in the above cause be included in the record on appeal:

1. Bill of Complaint.
2. Answer.
3. Amendment to answer.
4. Stenographic transcript of testimony taken or stipulated at the trial, as follows:

   Session of April 11, 1939:

   Page 1, Entire page.

   Page 66, line 5 to line 21, inclusive.

   Page 77, line 6 to line 27, inclusive.

   Session of April 12, 1939:

   Page 112, line 5 to page 123, line 4, inclusive.

   Page 138, lines 8 to 10 incl., and line 26 to page 139 line 1 incl.

   Page 139 lines 14 to 16 inclusive.

   Page 144, line 3 to end of session.

   Session of April 13, 1939:

   Page 153, line 1 to "Mr. Davis" on page 173, line 3 incl.

   Page 173, line 21 to page 174, line 8 inclusive.

   Page 174, line 25 to page 175, line 7 inclusive.

   At this point include in the record the following note:

   The parties thereupon on April 13, 1939, submitted to the Court Proposed Findings of Fact

agreed to by both parties and the Court on April 17, 1939, so found the facts and filed them with its conclusions of law overruling these defenses. Said Findings of Fact and Conclusions of Law are printed herein at pages 838 to 846.

Thereafter, on October 25, 1939, the Court resumed hearings on the other issues and the following proceedings were had:

Session of Oct. 25, 1939:
- Page 41, line 11 to line 15, inclusive.
- Page 42, line 4 to page 82, line 5, inclusive.

Session of Oct. 26, 1939:
- From beginning to page 177, line 11, inclusive.

Session of Oct. 27, 1939:
- Page 190, line 17 to page 196, line 6, inclusive.
- Page 196, line 19 to page 204, line 2, inclusive.
- Page 205, line 17 to page 273, line 15, inclusive.

Session of Oct. 28, 1939:
- From beginning to page 294, line 20, inclusive.
- Page 295, lines 4 to 8, inclusive.
- Page 295, line 16 to end of session, inclusive.

Session of Oct. 31, 1939:
- From beginning to page 368, line 21, inclusive.
- Page 369, line 21, to end of session, inclusive.

Session of Nov. 1, 1939:
- From beginning to page 508, line 11, inclusive.
- Page 510, line 6, to page 519, line 17, inclusive.

Session of Nov. 2, 1939:
- From beginning to page 541, line 10, inclusive.
- Page 541, line 23 to page 591, line 7, inclusive.
- Page 596, line 18 to page 603, line 4, inclusive.
- Page 604, line 1 to page 610, line 1, inclusive.
- Page 613, line 4 to line 10, inclusive.

Session of Dec. 13, 1939:
- Page 676, line 28, to page 677, line 7, inclusive.
- Page 708, line 18, to line 25, inclusive.

Plaintiff's Exhibit 26—stipulated testimony of Graham and others, together with stipulation relating thereto and the following note:

The Exhibits referred to in this stipulation were offered separately at the trial and were marked with the same identifying numbers, respectively, as referred to herein and are reproduced in this record as part of the trial Exhibits.

Plaintiff's Exhibit 27—stipulated testimony of Friis and others, together with stipulation dated October 19, 1939, relating thereto and the following note:

The Exhibits referred to in this stipulation are reproduced in this record at pages 1379 to 1403.

Plaintiff's Exhibit 28—stipulated testimony of Betts and others, together with stipulation dated October 19, 1939, relating thereto and the following note:

The Exhibits referred to in this stipulation are reproduced in this record at pages 1404 to 1461.

5. Findings of fact and conclusions of law filed April 17, 1939.

6. Findings of fact and conclusions of law filed Dec. 26, 1939.

7. Interlocutory Judgment.

8. Supersedeas Order.

9. Supersedeas Bond.

10. Notice of Appeal.

11. Exhibits to be printed in the record as follows: Plaintiff's Exhibits Nos. 1, 2A, 2B, 2B-1, 3A, 3B, 4 to 11, inclusive, 13, 14A, 14B, 15 to 18, inclusive, 20 to 23, inclusive, 24A, 24B, 25, 29.

Defendant's Exhibits Nos. A to R, inclusive, T to Z, inclusive, AA to MM, inclusive.

Exhibits accompanying Plaintiff's Exhibit 27, marked Defendant's Exhibit 9, 9A, and 9B-1 to 9B-7, inclusive, in the case of RCA Victor Company, Inc. v. Hazeltine Corporation.

Exhibits accompanying Plaintiff's Exhibit 28, marked Plaintiff's Deposition Exhibits Nos. 1-A, 1-B, 2, 3-A, 3-B, 3-C, 4-A, 4-B, 4-B-1, 4-C, 4-C-1, 4-D, 4-E, 4-E-A, 5, 5-1, 6-A, 6-B, 6-B-A, 7, 7-A, 8-A, 8-B, 8-C, 9-A to 9-F, inclusive, 10, 12 to 18, inclusive, in the case of RCA Victor Company, Inc. v. Hazeltine Corporation.

12. Exhibits to be certified to the Court of Appeals as physical exhibits:
Plaintiff's Exhibits Nos. 2, 3, 14, 19.
Defendant's Exhibit No. S.

13. This stipulation.

14. Stipulation re comparison of record.

15. Clerk's Certificate.

Pennie, Davis, Marvin & Edmonds,
By R. M. Adams.
Counsel for Plaintiff.
Attorneys for Plaintiff,
3053 Penobscot Building,
Detroit, Michigan.

Darby & Darby,
By Floyd H. Crews.
Counsel for Defendant.

Rosin & Ellmann,
Attorneys for Defendant,
1041 Penobscot Building,
Detroit, Michigan.

Dated: Feb. 12, 1940.

STIPULATION RE COMPARISON OF RECORD

(Filed April 30, 1940)

It is Hereby Stipulated by and between the attorneys for the respective parties hereto that the Record on Appeal as printed be certified and transmitted by the Clerk of the United States District Court for the Eastern District of Michigan to the United States Circuit Court of Appeals for the Sixth Circuit without comparison.

Darby & Darby,
By Floyd H. Crews.
Attorneys for Appellant.
Pennie, Davis, Marvin & Edmonds,
By R. M. Adams.
Attorneys for Appellee.

Dated: New York, N. Y., April 27, 1940.

ORDER EXTENDING TIME FOR FILING RECORD

(Filed March 2, 1940)

Upon reading and filing the Stipulation of counsel for the parties hereto agreeing to an extension of time to April 5th, 1940, for the filing of the record on appeal.

It Is Hereby Ordered that the time for filing the record on appeal is hereby extended to April 5th, 1940.

Edward J. Moinet,
District Judge.

STIPULATION AND ORDER EXTENDING TIME FOR FILING RECORD

(Filed April 4, 1940)

It Is Hereby Stipulated between counsel for the parties hereto that the time within which the record on appeal may be filed with the Court of Appeals be and the same hereby is extended to April 26, 1940.

Pennie, Davis, Marvin & Edmonds,
By R. M. Adams,
Counsel for Plaintiff.
Darby & Darby, By Floyd H. Crews,
Counsel for Defendant.

New York, New York,
March 29, 1940.

It is so ordered.

Arthur F. Lederle,
U. S. D. J.

Detroit, Michigan,
April 4, 1940.

CLERK'S CERTIFICATE

Eastern District of Michigan,
Southern Division.—ss:

I, ..., Clerk of the District Court of the United States for the Eastern District of Michigan, Southern Division, do hereby certify the above and foregoing to be a true and complete transcript of the proceedings had of record made in accordance with the stipulation as to record filed in this Court in the cause entitled Hazeltine Corporation v. Detrola Radio & Television Corporation, No. 8337, as the same appear from the original records and files thereof now remaining in my custody and control.

In Testimony Whereof, I have hereunto set my hand and affixed the seal of the said Court at my office in the City of Detroit in said district this ...... day of March, A.D., 1940.

....,
Clerk.

(Seal)

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[fol. 1470] PROCEEDINGS IN THE UNITED STATES CIRCUIT COURT OF APPEALS FOR THE SIXTH CIRCUIT

CAUSE ARGUED AND SUBMITTED—October 16th, 1940

Before Hicks, Simons & Allen, JJ.

This cause is argued by Samuel E. Darby for Appellant and by William H. Davis for Appellee and is submitted to the court.

DECREE—Entered December 9, 1940

Appeal from the District Court of the United States for the Eastern District of Michigan

This cause came on to be heard on the transcript of the record from the District Court of the United States for the Eastern District of Michigan, and was argued by counsel

On Consideration Whereof It is now here ordered, adjudged and decreed by this Court that the decree of the said District Court in this cause be and the same is hereby affirmed.

[fol. 1471] OPINION—Filed December 9, 1940

[fol. 1472] [Stamp:] Filed Dec. 9, 1940. John W. Menzies, Clerk

UNITED STATES CIRCUIT COURT OF APPEALS, SIXTH CIRCUIT

No. 8632

DETROLA RADIO & TELEVISION CORPORATION, Appellant,

v.

HAZELTINE CORPORATION, Appellee

Appeal from the United States District Court for the Eastern District of Michigan, Southern Division

Decided December 9, 1940

Before Hicks, Simons and Allen, Circuit Judges

ALLEN, Circuit Judge:

Appeal from a decree holding Reissue Patent 19,744 valid and infringed, and granting appropriate equitable

relief. All of the claims except claim 8 are in suit. The reissue patent was granted on October 29, 1935, on an application therefor dated September 26, 1934. The original patent (1,879,863) was issued September 27, 1932, to Harold A. Wheeler, on a divisional application dated July 7, 1927. The appellee is assignee of the patent and the reissue.

The patent is for a hook-up circuit for a radio broadcast receiver, and relates to "amplifiers utilized in modulated carrier-current signaling systems wherein the limit of amplification is automatically maintained substantially at a predetermined level." The purpose of the invention, as stated in the specifications, is automatically to control the volume of the amplified signal voltage where amplifiers are employed and thus to effect "automatic amplification control." The patented device is used today in all well-known radio receivers manufactured in the United States. Over [fol. 1473] four million Philco receivers utilizing the Wheeler method of automatic volume control had been sold up to the time of trial, and much of their success is attributed to the use of the Wheeler diode system.

In addition to the usual defenses of lack of invention and non-infringement, appellant asserts that the reissue patent was not properly granted because (1) a patent held invalid as disclosing no invention cannot be validly reissued; (2) the statutory requirements were not complied with, and (3) laches intervened.

Claims 1, 5, 6 and 10 of the original Wheeler patent were held void in the Eastern District of New York (Hazeltine Corp. v. Abrams, 7 Fed. Supp. 908, 914) on the ground that they disclosed no invention over Affel, 1,574,780, Bjornson, 1,666,676, and Heising, 1,687,245. These patents had not been cited by the Patent Office in the proceedings with reference to Wheeler's application for the original patent. Affel and Heising relate to transmission systems only. Langley, expert for the Hazeltine Corporation in the trial in the District Court of New York, testified that Affel and Heising did not anticipate because Wheeler's device related solely to the radio receiver. The District Court held that the original Wheeler patent was not limited to a receiving system because each claim referred to a "signaling system," and therefore, considered that the differentiation suggested by Langley was not stated in the claims. The court in its opinion (p. 913) suggested the narrowing of the claims, stating that "It may well be that if the Wheeler

claims in issue were narrowed to the improvements defined in his specification, weight could be attached to the Langley comparison. That of course is not permissible since it would mean a rewriting of the claims." The Second Circuit affirmed the judgment of the District Court [Hazeltine Corp. v. Abrams, 79 Fed. (2d) 329], although it differed from the District Court with reference to the scope of the Wheeler patent, indicating that consideration of the claims in the light of the specifications showed that Wheeler's device was intended to be limited to a radio receiver. However, it agreed with the District Court that the patent disclosed no patentable invention. Prior to the decision in the Second Circuit appellant had applied for a reissue in which the scope of the original claims was narrowed substantially in accordance with the suggestions of the District Court, and the reissue patent was subsequently granted.

Appellant urges that a patent held to be invalid because it discloses no patentable invention, as is the case here, [fol. 1474] cannot be cured by reissue. It relies strongly for this contention upon Penn Electrical & Mfg. Co. v. Conroy, 185 Fed. 511 (C. C. A. 3), which states broadly that where a patent for a process has been adjudged invalid for lack of patentable invention in that the process was not new, the case is not one of insufficiency, overstating, inadvertence, accident or mistake entitling the patentee to a reissue. That was a case in which the validity of the reissue patent was attacked by the same party which had attacked the validity of the original patent, and therefore an issue of res judicata was involved. The alleged infringer here was not a party to the Hazeltine case decided in the Second Circuit. In Traitel Marble Co. v. U. T. Hungerford Brass & Copper Co., 18 Fed. (2d) 66 (C. C. A. 2), where a similar contention was made with reference to the validity of the reissue, and where the parties, as here, were not identical, the court stated that the decision in the former suit was not conclusive in a second suit involving other parties, even though the original patent had been declared invalid for anticipation, and the Penn Electrical & Mfg. Co. case was distinguished. Also in the Penn Electrical & Mfg. Co. case the court stresses the fact that the "vice" of the original patent was not that a patentee had claimed as new more than he had a right to claim, from which observation an inference might well be drawn that in such case the Third Circuit would have held the reissue

valid. Here the reissue patent was applied for on that specific ground. The court in the Hazeltine case (7 Fed. Supp., at 914), had stated that Wheeler, in the original patent, had claimed more than he had a right to claim as new, and Wheeler, in his application for reissue, conceded the fact and relied on it. We conclude that the Penn Electrical & Mfg. Co. case is not controlling here.

A ruling diametrically opposed to that sought by appellant, to the effect that a valid reissue may be granted where the original patent has been declared invalid, was announced by this court in Van Kannel Revolving Door Co. v. Winton Hotel Co., 276 Fed. 234. In that case the reissue patent had been attacked upon the ground that the original patent had been declared invalid. The court, at page 238, said:

"The specification of the 1906 patent was broad enough to support the claims contained in the reissue. There was no change in the drawings, and the changes made in the specification were only in the interest of further elaboration and [fol. 1475] explanation. They introduced no substantial new matter. The substantial basis of the application for reissue was that the claims were not commensurate with the invention. If Van Kannel, through his solicitor, without intending to do so, drafted or accepted claims not commensurate with the invention, such act is an 'inadvertence' within the meaning of Rev. Stat. § 4916 (Comp. St. § 9461), which entitled him to a reissue. What constitutes the 'same invention' is not to be determined by the claims of the original patent, but from the description and such other evidence as the commissioner may deem relevant. Whether the act was inadvertent is a question primarily for the Patent Office, whose decision will not be reviewed unless inconsistent with other facts appearing in the record. American Co. v. Porter (C. C. A. 6), 232 Fed. 456, 146 C. C. A. 450. It is not important whether the patentee considered the claims, as drawn, too broad, rather than too narrow. Claims may be either narrowed or broadened to express the real invention. American Co. v. Porter, supra; Specialty Co. v. Ashcroft (C. C. A. 2) 213 Fed. 35, 40, 129 C. C. A. 629; Robert v. Krementz (C. C. A. 3), 243 Fed. 877, 881, 156 C. C. A. 389. In our opinion the decision of the Patent Office that the reissue was proper is not inconsistent with facts otherwise appearing in the record. The proposition

that the original claims were not sufficient to protect the real invention is not overthrown by the fact that the holdings of invalidity of the claims of the 1906 patent, so far as made, were based upon lack of invention."

This case is squarely controlling here. Wheeler introduced no new matter, and the application for reissue showed that the claims as originally drafted were not commensurate with the invention. The fact that the original patent was held invalid does not defeat the reissue patent. Cf. Maitland v. S. Goetz Mfg. Co., 86 Fed. 124 (C. C. A. 2), in which the patent had also been held invalid upon the ground of lack of invention, but the reissue was sustained.

Appellant urges, however, that the application does not comply with the statute and is false on its face. It relies upon the fact that the original oath filed with the petition for reissue recited no facts tending to show inadvertence, accident or mistake, as required by Rule 87 of the Rules of Practice of the United States Patent Office,[1] and also [fol. 1476] upon the fact that Wheeler himself is a radio patent expert, and therefore could not have drawn the original claims inadvertently. But the examiner, citing Union Switch & Signal Co. v. Louisville Frog, Switch & Signal Co., 73 Fed. (2d) 550 (C. C. A. 6), notified Wheeler of the insufficiency of the oath upon the ground that it did not comply with the rule. Wheeler then filed an amended and supplementary oath in which he stated that in the original patent application he had claimed as his invention "more than he had a right to claim as new," specified that the claims embodying such improper claims were 1, 5, 6, 9 and 10 of the original patent, and set forth in detail the fact that the specifications described a radio receiver to which certain of his claims did not apply; that he was not apprised of this fact until the adverse decision in the District Court (Hazeltine Corp v. Abrams, supra),

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[1] Rule 87.

"Applicants for reissue, in addition to the requirements of the first sentence of Rule 46, must also file with their petitions a statement on oath as follows: * * * (d) Particularly specifying the errors which it is claimed constitute the inadvertence, accident or mistake relied upon, and how they arose or occurred."

and that the reissue was sought in order that the claims might be made to correspond to the invention. While Wheeler has prepared numerous applications for patents in radio matters, it appears that in this particular patent application his work was directed mostly toward the examination of the specifications describing his device, already successfully operated and publicly demonstrated, and that he took the advice of his solicitor with reference to the drafting of the claims. It was agreed by both parties in the findings of fact that the applications for the original patent and for the reissue were prepared by Wheeler's patent solicitor in close collaboration with Wheeler, and that this was done "honestly without fraudulent or deceptive intention, and without intending to claim as Wheeler's invention or discovery more than he had a right to claim as new." This finding of fact disposes of any issue of fraud or deception. If as a matter of law drafting claims not commensurate with the invention revealed in the specifications constitutes inadvertence, unless deliberate or fraudulent, then the essential facts were set forth in the application for reissue, and in the amended and supplemental oath. But the fact that Wheeler unintentionally and in reliance upon his solicitor drafted or accepted claims not commensurate with the invention disclosed in the specifications, constitutes an inadvertence within the meaning [fol. 1477] of the statute. American Automotoneer Co. v. Porter, 232 Fed. 456, 460 (C. C. A. 6); Van Kannel Revolving Door Co. v. Winton Hotel Co., supra. There is no conclusive evidence here, such as existed in the Union Switch & Signal Co., case, supra, that there was no accident, inadvertence or mistake, and upon this point we see no reason for overruling the decision of the Patent Office. Cf. Cincinnati Rubber Mfg. Co. v. Stowe-Woodward, Inc., 111 Fed. (2d) 239, 242 (C. C. A. 6).

Nor is the reissue patent invalid because of laches in the application. The original patent was issued September 27, 1932, and the application for reissue was filed September 26, 1934. It was not until August 6, 1934, that the District Court in New York held the claims invalid, and Wheeler became aware for the first time of the possible necessity of cancelling the claims. The appellee was entitled to rely upon and litigate the original claims, and had a right to wait for the decision of the Circuit Court

of Appeals before definitely abandoning them. Cincinnati Rubber Mfg. Co. v. Stowe-Woodward, Inc., supra; France Mfg. Co. v. Jefferson Electric Co., 106 Fed. (2d) 605, 610 (C. C. A. 6); Triplett v. Lovell, 297 U. S. 638. As Wheeler's reissue was a narrowing, instead of a broadening reissue, the doctrine of equitable estoppel declared in Sontag Chain Stores Co., Ltd., v. National Nut Co., 310 U. S. 281, does not apply.

Appellant relies upon Maytag Co. v. Hurley Machine Co., 307 U. S. 243, as authority for a further contention that the reissue patent is invalid because it failed to disclaim all of the invalidated claims of the original patent. This decision, which covers a case where a patentee had unreasonably neglected and delayed in suing upon or disclaiming a claim not definitely distinguishable from another adjudged invalid for anticipation and disclaimed, is not in point here, where claim 1 of the reissue patent is not in substance the same as claim 10 of the original patent. In addition to what was formerly described, claim 1 adds the essential element of the "high resistance connected between the rectifier anode and the amplifier cathode." The language of the Maytag decision (p. 245) in fact supports the right of appellee to sue upon claim 1 of the reissue.

We next consider the questions of patentability and invention, and on these points the decree also must be affirmed. [fol. 1478] Wheeler's patent relates to volume control in a radio receiver. Claim 1 is typical, and is printed in the margin.[2]

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[2] Claim 1.

"In a signal receiver having a carrier-frequency amplifier which includes at least one vacuum tube having a cathode and a control electrode, a two-electrode rectifier coupled to the output circuit of said amplifier, a high resistance connected between the rectifier anode and the amplifier cathode, means including said resistance for maintaining the average potential of said anode normally negative relative to at least part of said amplifier cathode and increasingly negative with increasing amplified signal output from said amplifier, and a direct-current connection from said anode back to said amplifier control electrode whereby the amplification of said amplifier is regulated automatically."

The carrier wave which is sent out through space from the broadcasting station is a high-frequency wave modulated at the transmitter by a low-frequency wave superimposed upon it. This wave is a high-frequency oscillation which when received at the antenna of the radio receiver vibrates so rapidly that the ear cannot detect it. In the receiver, the carrier wave is amplified and then conducted through the detector, where it is rectified so that it becomes a unidirectional or direct current. The rectified signal varies in accordance with the signal modulated by the sound wave at the transmitter and reproduces the original signal, which after amplification is conducted to the loud-speaker to be heard by the listener. In the early period of radio, problems of "blasting" and "fading" developed, to the solution of which Wheeler's device was particularly directed. Blasting is the term applied to the harsh and distorted sounds that came from a radio receiver of the earlier type, when the operator tuned from a weak to a strong station. When a weak signal was received, a high degree of amplification was employed in the receiver in order to make the weak signal audible at the loud-speaker. If this degree of amplification was retained when the operator tuned in on a strong station, the signal was overamplified and the operator was compelled to adjust not only for tuning to wave length, but also for volume control. Fading was due to atmospheric conditions which caused signals to vary in intensity, changing from strong to very weak signals. Wheeler's invention secured automatic compensation for inequalities in the received radio-frequency signal, with corresponding increase or decrease in the degree of amplification, so that the amplification of the strong signals would be toned down and the weak signals would be strengthened.

Wheeler's drawings disclose a three-stage radio-frequency amplifier followed by a rectifier, a two- or three-stage audio-frequency amplifier, and a loud-speaker em- [fol. 1479] bodied in a complete radio receiver. The rectifier employed is a two-electrode rectifier. The radio-frequency amplifier amplifies the incoming signal intercepted on the antenna through the successive stages. The amplified signal current is then rectified, and the rectified pulsating current, after being successively amplified by the audio-amplifiers, is reproduced as sound at the loud-speaker.

The gist of the invention, as disclosed in the specifications, lies in the fact that the degree of amplification effected in the radio-frequency amplifier is automatically controlled by a biasing potential obtained by rectifying the modulated signal carrier in a two-electrode rectifier having a high resistance connected between the filament and the anode of the rectifier through which the pulsating rectified current flows, thereby developing a negative voltage which is applied to the grid of the first radio frequency stage. When the rectified signal current increases with signal output beyond a predetermined value, there is developed at the anode terminal of the rectifier sufficient increase of the negative biasing voltage, which in turn is impressed upon the grid of the first stage amplifier to reduce amplification of this tube. Conversely, as the magnitude of the rectified current decreases with decreasing signal strength, the voltage at the anode terminal of the rectifier becomes less negative, and the negative biasing voltage impressed upon the grid diminishes so that the first radio-frequency amplifier effects an increased degree of amplification. Thus the volume of the reproduced signal is substantially uniform under all conditions.

An important feature of the Wheeler device is its use of the diode. The vacuum tube originally used for detection consisted of two electrodes, called diode. As the art developed, a third electrode or grid was interposed between the cathode and anode, thus constituting the triode. The triode could be used for amplification as well as detection, and hence for a number of years in the radio art it replaced the diode. The voltage upon the grid (sometimes called the grid bias or potential) is negative, relative to the potential of the filament, and repels the electrons which are emitted from the cathode as the current flows through the circuit, prevents or controls their attraction by the positive plate or anode, and thus decreases and controls the amplifying power of the tube. The use of the negative bias for this purpose was old in the art. Where former inventors had derived their control potential through the [fol. 1480] triode, from the B battery, Wheeler, using the diode, derived it directly from the amplified signal.

Appellant urges that there is no invention in the use of the diode as opposed to the triode; but Wheeler's device does not merely embody the diode. It discloses the use of the diode united with a high external resistance opposed

to the relatively low internal resistance of the diode, with a consequent linear response which results in better automatic volume control than had ever before been secured. We agree with the District Court that this combination of the diode and the high resistance creating the negative bias at the grid in direct proportion to the amplified modulated carrier voltage is a new and useful improvement in the radio art, requiring the exercise of inventive genius. The device secures automatic volume control. The elements of the combination were old, but the combination was new, and the result was new. This constitutes invention. Forestek Plating & Mfg. Co. v. Knapp-Monarch Co., 106 Fed. (2d) 554, 557 (C. C. A. 6).

In the triode, energy is obtained from an external source or battery, and not from the amplified signal. The control bias voltage is dependent upon the battery voltage. Therefore, in the three-electrode detector circuits, an adjustment must be made in order to increase or decrease the requisite amplification to compensate for variations of signal strength. In Wheeler, the resistance which is high compared with the resistance of the diode, makes the diode a minor element in determining the voltage of the rectified signal. This record supports the assertion of the specifications that as the diode rectifier does not amplify, is not critical, and requires neither anode nor biasing battery, Wheeler requires no adjusting device, such as a potentiometer, to accommodate the control bias to any particular combination of tubes and B battery voltage.

Another important feature of Wheeler is that the device secures linear response. Since the control voltage is derived directly from the amplified signal, it is always directly proportional to the amplified signal voltage, and the "average signal amplitude which is equal to the carrier wave amplitude and independent of the degree of modulation" is kept constant. But in a triode such as was used at the time of Wheeler's invention, the rectified voltage was proportional to the square of the applied voltage, and not directly. It was admitted by Kelly, appellant's expert, that a diode detector used in series with the high resistance gives linear response, that the use of the triode results in [fol. 1481] a "square law action," and that to get any linear characteristic using a triode, both the B battery potential and the C battery potential have to be increased. He could not recall any radio receiver using a triode that

was linear in its action. These distinct changes in operation work a substantial advance in automatic volume control.

The patent is not anticipated. Affel, 1,574,780, and Friis, 1,675,848, use the triode detector, and therefore do not secure the linear characteristic of Wheeler. Affel develops his control potential before amplification, and therefore, as appellant's expert testified, cannot secure a signal strong enough for linear rectification. Heising, 1,687,245, uses a diode, as also does Sleepian, 1,455,768. But the purpose of these two patents is entirely distinct from Wheeler, and neither of them attempts nor secures automatic control. Heising's device is for use in a transmitter. Sleepian does not have a constant potential, and he uses his diode for the purpose of making the response proportional to the signal received.

Experts for both parties agree that the disclosure closest to Wheeler is Evans, 1,736,852 and 1,869,323. Evans also discloses the use of a triode, and does not produce the current for biasing the grid control from the amplified and rectified signal, but produces it from a battery. The control potential, therefore, depends upon the adjustment of the B battery and the C battery to the triode, which in addition has a non-linear characteristic.

Appellant contends that its device is patterned after Evans and the other above-mentioned patents; but there is no merit in this contention. While appellant uses a multipurpose tube which contains a diode and triode, it concedes that it employs the diode only for the purpose of automatic volume control. It secures its energy just as Wheeler, from the amplified signal itself, and uses a high resistance through which it develops the linear characteristic with the resulting control voltage which is directly proportional to the amplified signal voltage. These features are the gist of the Wheeler invention, and appellant has paid the compliment of adopting them. As held by the District Court, appellant's receivers embody the invention disclosed in the reissue patent.

The decree is affirmed.

[fol. 1482] United States Circuit Court of Appeals for the Sixth Circuit

I, J. W. Menzies, Clerk of the United States Circuit Court of Appeals for the Sixth Circuit, do hereby certify that the

foregoing is a true and correct copy of record (3 volumes) and proceedings in the case of Detrola Radio & Television Corporation, Appellant, vs. Hazeltine Corporation, Appellee, No. 8632, as the same remains upon the files and records of said United States Circuit Court of Appeals for the Sixth Circuit, and of the whole thereof.

In Testimony Whereof, I have hereunto subscribed my name and affixed the seal of said Court at the City of Cincinnati, Ohio, this 16th day of December, A. D. 1940.

J. W. Menzies, Clerk of the United States Circuit Court of Appeals for the Sixth Circuit. (Seal.)

[fol. 1483] SUPREME COURT OF THE UNITED STATES

ORDER ALLOWING CERTIORARI—Filed February 3, 1941

The petition herein for a writ of certiorari to the United States Circuit Court of Appeals for the Sixth Circuit is granted.

And it is further ordered that the duly certified copy of the transcript of the proceedings below which accompanied the petition shall be treated as though filed in response to such writ.

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